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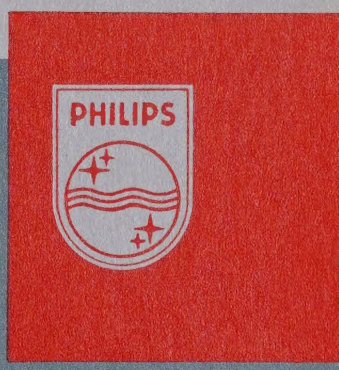

LEAKAGE CURRENT - BREAKDOWN VOLTAGE
AND
TERAOHM - METER

PM 6509

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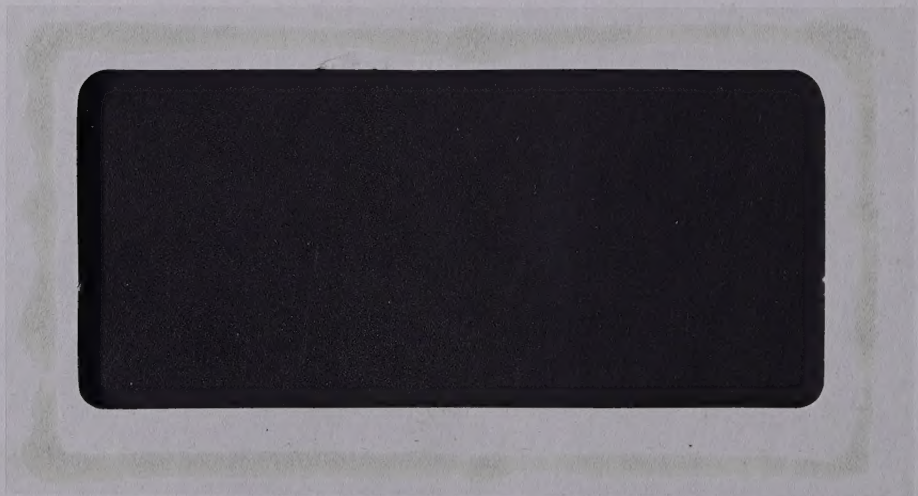
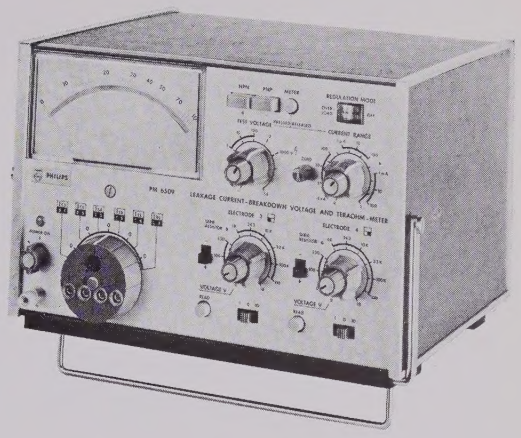
9499 520 03911

1/269/1/01





PHILIPS

Manual

LEAKAGE CURRENT - BREAKDOWN VOLTAGE

AND

TERAOHM - METER

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1/269/1/01

IMPORTANT

In correspondence concerning this instrument, please quote the type number and the serial number as given on the type plate at the rear of the instrument.

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GENERAL INFORMATION

I *Introduction*

LEAKAGE CURRENT-BREAKDOWN VOLTAGE AND TERAOHM-METER PM 6509.

This PHILIPS measuring instrument has been especially designed for extremely sensitive measurements on multi-pole semi-conductors. Due to the many combinations that are possible this measuring instrument is suited for practically all types of semi-conductor, and particularly for measurements in which the third and the fourth electrode are connected to potentials and/or resistors. In addition, the instrument is extremely suitable for measuring very high resistances (up to 100 Tera-Ohm), insulation resistances, leakage currents of capacitors, direct currents in the pA order of magnitude etc,

When employed as current and voltage source the instrument may be used for various purposes, as all supply sources are stabilised and shortcircuit proof.

Furthermore, the instrument may be used as an amplifier with variable integrating time.

The external control facility permits of using the instrument in inspection lines or external programming

The extensive field of applications of this measuring instrument enables its use in practically all fields of electronics.

II *Block diagram*

For explaining the working principle of this instrument we start with the mode selector, whose control knob contains the sockets for connecting the semi-conductor under test. The four sockets are connected to the supply sources in the instrument, so that by turning the knob 6 different supply voltage combinations are available on the sockets.
In the block diagram one of these combinations is shown; the changeover contacts are indicated by means of a dotted line.
The arrangement of the 4 electrodes is always shown near the relevant switch position. The upper section refers to the electrodes to which the main circuit is connected; the lower section represents the auxiliary sources which refer to the second electrode in the main circuit (in our example B and S in respect to E = Emitter).

The main supply of the junction under test is a regulated constant voltage source with steep cross-over to constant current. As soon as the preset current value is reached, the current remains constant and the voltage will drop at decreasing resistance in the semi-conductor under test. The generator is a controlled oscillator whose rectified and smoothed output voltage is applied to the semi-conductor under test via the polarity switch (NPN – PNP) and the shunt switch. Two differential amplifiers control the oscillator as regards voltage or current in the output circuit, in accordance with the preset values of the current and voltage control.

An indicator shows the control method; dependent on the mode of operation of the supply source the pointer deflects to the left or to the right.
The measuring instrument indicates the current or voltage through the test circuit, dependent on the position of the 'METER' button. The voltage is determined by comparing the test voltage (across series resistors) with a reference voltage. The amplifier controls the output voltage to the preset value.
The current in the test circuit is determined by a very sensitive measuring amplifier. At the output of this amplifier a moving coil instrument is included which indicates the current flowing through the test circuit. The output voltage of the measuring amplifier moreover drives the control amplifier. The latter ensures that in the case of current control the current in the test circuit exactly corresponds to the preset value. A zero control permits of accurate balancing of the amplifier and of compensation for unbalances caused by currents arising as a result of insulation leaks.
The control signal for voltage or current control is first applied to the 'oscillator amplitude control switch'. This switch controls the oscillator to the preset voltage or current value.
Internal or external series contacts ensure that the generator voltage cannot exceed the preset value, in case of e.g. switching over. External control (on-off) of the generator is also possible for series measurements. The generator output voltage or current then each time increases from zero to the desired value.

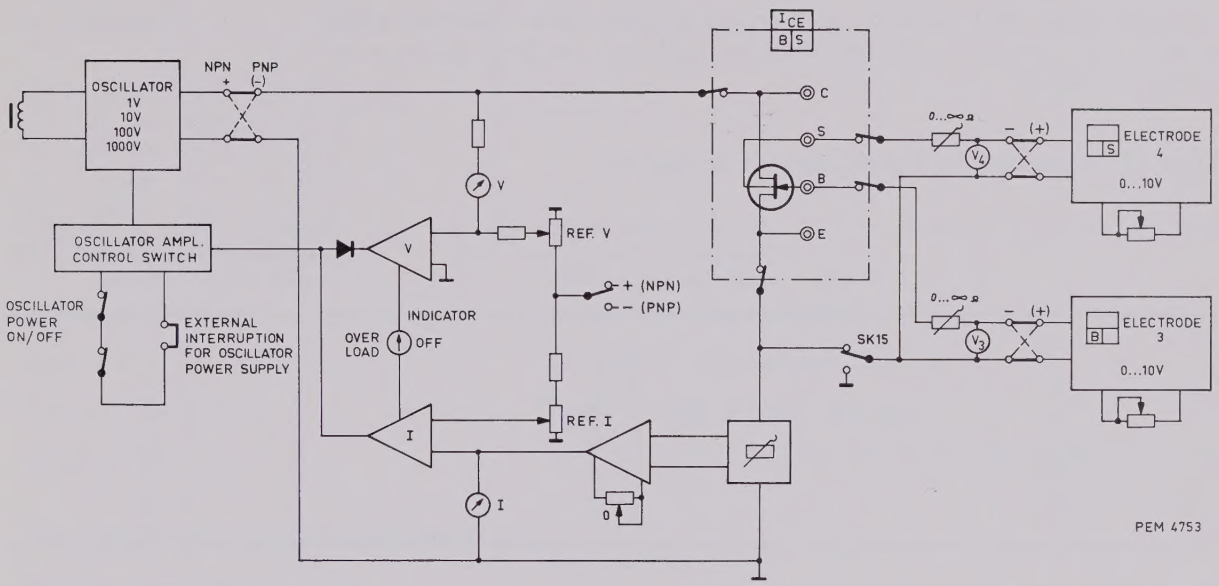


Fig. 1. Block diagram

III *Technical data*

Numerical values with indication of tolerances are guaranteed; numerical values without tolerances serve merely for information and represent the properties of an average instrument.

Types of measurements as regards electrode arrangement

Test current circuit 1. + 2. electrode	Auxiliary voltage electrode 3; connection to 3rd electrode, with respect to 2nd electrode	Auxiliary voltage of electrode 4; connection to 4th electrode, with respect to 2nd electrode
I_{CS}	B – S	E – S
I_{CE}	B – E	S – E
I_{CB}	E – B	S – B
I_{EB}	C – B	S – B
I_{ES}	C – S	B – S
I_{BS}	C – S	E – S

Moving-coil instruments

Measuring value indicator	With logarithmic scale, class 1, accuracy relative to scale value: 1.5%
Voltage measuring ranges	1 V, 10 V, 100 V, 1000 V
Current measuring ranges	100 pA, 1 nA, 10 nA, 100 nA, 1 μA, 10 μA, 100 μA, 1 mA, 10 mA, 100 mA

Mode indicator

Indication at	constant voltage control: 'V' constant current control: 'A' overload or short-circuit: 'OVERLOAD' open control circuit: 'OFF'

Test current or voltage source

Voltage ranges (constant voltage supply)	0.1 ... 1.1 V max. current 200 mA 1 ... 11 V max. current 200 mA 10 ... 110 V max. current 20 mA 100 ... 1100 V max. current 2 mA
Ripple voltage	$< 0.5\%$ of f.s.d.
Effect of load variations	$\leqslant 1\ \%$
Effect of $\pm$ 15% mains voltage variations	$\leqslant 0.5\%$
Max. power in output circuit	$\leqslant$ 0.1 Wsec.
Max. contact load due to interruption of the power supply in external circuit	2 mA, 1 V
Switching-on delay	approx. 150 ms.

Current ranges

Control range	*Voltage drop*	*Accuracy*	*Nonlinearity*
0 ... 100 pA	100 μV	± 3%	± 1%
0 ... 1 nA	100 μV	± 3%	± 1%
0 ... 10 nA	100 μV	± 3%	± 1%
0 ... 100 nA	100 μV	± 3%	± 1%
0 ... 1 μA	max. 1 mV	± 1%	± 0.5%
0 ... 10 μA	max. 1 mV	± 1%	± 0.5%
0 ... 100 μA	max. 1.1 mV	± 1%	± 0.5%
0 ... 1 mA	max. 1.1 mV	± 1%	± 0.5%
0 ... 10 mA	max. 1.1 mV	± 1%	± 0.5%
0 ... 100 mA	max. 1.2 mV	± 1%	± 0.5%

Temperature stability	± 15 pA or 1% per 10 °C
Zero shift	± 1 nA with potentiometer 'ZERO'
Current control range	from 5 ... 100% of measuring range
Output value	100% current = 1 V ± 1% (at a min. load resistance of 1 kΩ).

Adjustable integration time for hum suppression

Two auxililiary voltage sources:

Control ranges	0 ... 1 V and 0 ... 10 V ± 5% zero adjustment 1 V – 0 – 10 V
Effect of ± 15% mains voltage variations	⩽ 1%
Effect of load variations of 0 ... 5 mA	⩽ 0.5%
Short-circuiting current	⩽ 60 mA
Polarity	switchable
Additional series resistors that may be included	0,100 Ω, 330 Ω, 1 kΩ, 3.3 kΩ, 10 kΩ, 33 kΩ, 100 kΩ, ∞.
Voltage measurements	by means of push-button, reading 0 ... 1 V or 0 ... 10 V on moving-coil instrument

Connection of the common point of both sources to reference electrode or to earth by means of internal toggle switch.

Resistance measurement

At constant current supply max. measuring range	10 ohm ... 10 Tera-ohm (10^{13} ohm) direct reading on logarithmic scale
At constant voltage supply, max. measuring range	10 ohm ... 100 Tera-ohm (10^{14} ohm) reciprocal indication (measuring value = $\frac{U)}{I}$

Outputs for external valuation

Recorder output for voltage measurements	350 mV for f.s.d.
Recorder output for current measurements	1 V for f.s.d.

Inputs for external control

Control of the test voltage adjustment by resistors
Switching on or off of the test voltage by external contact

Power supply

Mains voltage	115 V or 230 V, ± 15%
Mains frequency	40 ... 60 Hz
Power consumption	15 VA.

Mechanical data

Dimensions	Height 180 mm Width 287 mm Depth 255 mm
Weight	6 kg.

IV *Accessories*

Mains lead
2 fuses 200 mA, delayed action
Manual

Optionally available

PM 6544	Adapter for power transistors with SOT 9 casing (DIN 9A2)
PM 6545	Adapter for current gain measurements
PM 6549	Adapter for power transistors with TO 3 and TO 6 casings as well as for miniature iature
PM 6547	Adapter for RF transistors
PM 6548	Empty casing for mounting a special transistor socket

DIRECTIONS FOR USE

V *Installation*

A. ADJUSTMENT TO THE LOCAL MAINS VOLTAGE

Before the instrument is put into operation check that the setting of voltage adapter SK14 at the rear of the instrument is correct.

Mains voltages between 98 V and 132 V: 115 V setting

Mains voltages between 196 V and 264 V: 230 V setting

The rating of fuse VL1 (fig. 3) is 200 mA, delayed action, for the entire mains voltage range.

B. EARTHING

The instrument should be connected to a socket with rim earthing by means of the 3-core mains lead supplied. The rim earthing of the mains plug is connected to the instrument housing, so that normally the instrument is earthed via the mains cable.

If the instrument is connected to a socket without rim earthing it may be earthed via socket ⏚ (BU1) at the front of the instrument. Always ensure that connection to the mains and earthing comply with local safety regulations.

C. MODULAR SYSTEM

The dimensions of the instrument (4 modules) permit of combining it with other instruments of the modular system.

VI *Operation*

A. FUNCTIONS OF THE CONTROLS

SK1 A and SK1 B	Serves for polarity change-over of the test voltage source. The polarity indication (when the relevant button is depressed) refers to the first electrode.
SK1 C	This button serves for switching over the mode of the operation of the indicating instrument. Button depressed = Voltage measurement, in accordance with preselected measuring range of SK2, i.e. 1 V, 10 V, 100 V or 1000 V. Button released = Current measurements in accordance with preselected measuring range of SK3, 0.1 nA...100 mA.
SK2/R1	
SK2	Preselect switch for the voltage ranges.
R1	Potentiometer for adjusting the voltage in the relevant control range in the case of voltage control.
SK3/R3	
SK3	Preselect switch for the current ranges.
R3	Potentiometer for adjusting the current within the preselected range of SK3. This potentiometer is used in the case of constant current control.
SK4	Mains switch for switching on and off the instrument.
SK5	Mode selector. The sockets on the switch knob are connected to the relevant current or voltage sources in accordance with the indications in the squares. In the 0 positions all sockets are disconnected.
SK6 and SK8	Polarity switch for the 2nd and 3rd voltage source.
SK7 and SK9	Step switch for fixed resistance values between 0 and ∞. These resistors may be connected in series with the voltage sources of the 3rd and 4th electrodes.
SK10 and SK12	Non-locking push-buttons for connecting the measuring instrument for measuring the 3rd and 4th electrode voltage. The measuring range is determined by the position of SK11 and SK13.
SK11 and SK13	Selector for voltage range 1 V, 10 V or 0. In position 0 the current circuit of the relevant voltage source is connected direct or via resistors (of SK7 or SK9) to the reference electrode.
R4 and R5	Potentiometer for adjusting the auxiliary or reference voltage on the 3rd or 4th electrode. The control range is preselected with SK11 and SK13 respectively and for checking the voltage push-button SK10 and SK12, should be depressed.
SK14 (on rear)	Mains voltage adapter for 98...132 V and 196...264 V (see installation).
SK15 (on bottom)	Switch for changing over the earthing of the reference electrode of the auxiliary sources of the 3rd and 4th electrodes.

thus permitting of independent polarity adjustment. The + or – potential selected with these switches refers to the 3rd or 4th electrode, as the case may be.

3. Voltage or current control / Voltage or current limitation

One of the most essential sections of this measuring instrument is the combined supply source, which operates both as constant voltage source and as constant current source.

Up to the preset current value the supply source is voltage controlled and after reaching this value it is current-controlled.

This makes it possible to select the max. value for currents between 10 pA...100 mA. The control method is shown at the indicator.

As a result, exceeding of the max. permissible current during the test of a semi-conductor is practically impossible.

By depressing the 'METER' button the voltage present at the junction under test can be read off at any current.

Moreover, it is also possible to select an arbitrary voltage between 100 mV and 1000 V. Even in case of a decreasing or increasing current the voltage can never exceed the preset value, which is of special importance for break-down tests.

a. Voltage setting

Step switch SK2 makes it possible to select 4 meas uring ranges and 1 zero position. The three ranges 1 V, 10 V and 100 V are included in one group of the lower danger zone. A zero position serves in the first place for electrical and visual separation of the lower range steps from the H.T. step, which permits of voltage settings up to 1100 V.

Within these ranges the voltage can be adjusted from 5% to 110% of the nominal range value by means of control R1.

For reading the voltage on the meter button 'METER' (SK1c) should be depressed. The voltage can only be adjusted when mode selector SK5 is set to one of the six modes (not to 0).

The desired voltage range is selected by means of the range selector. Its nominal value corresponds to end of scale value 100 of the meter. Within this range adjustment to any intermediate value is possible by means of potentiometer R1, provided that the current limitation is not activated.

In this case the supply source operates as constant voltage source; this mode of operation is shown on the indicator whose pointer is at the triangular range 'V' (Fig. 6a).

In the case of an open control circiut the meter deflects to the bar 'OFF' at the right of the scale (Fig. 6b).

b. Adjusting the current limitation

The current limitation can be adjusted by means of range switch SK3 and potentiometer R3. The range selector has 10 steps, which are divided into the groups nA, μA and mA.

In the junction under test of the semi-conductor the current cannot exceed the preset current value, if e.g. the test voltage increases or if the resistance of the semi-conductor decreases.

As soon as the preset current is reached, it remains constant. Indication of the measuring value is effected with released 'METER' button. The end-of-scale value then corresponds to the selected range step. When the supply source operates as constant current source the pointer of the indicator will be at the triangular range 'A' (fig. 6c). When the supply source is overloaded the pointer of the indicator will be at the sector at the left of the scale 'OVERLOAD' (Fig. 6d).

This may occur e.g. in case of a short-circuit, when due to the high load the voltage in the measuring circuit is reduced to practically zero and when the current range is set to too high a value (e.g. 1000 V range, 10 mA).

Selection of a current range depends on the voltage, as each voltage step has a certain permissible current. When the current exceeds the max. permissible value for that voltage range, the indicator pointer will be

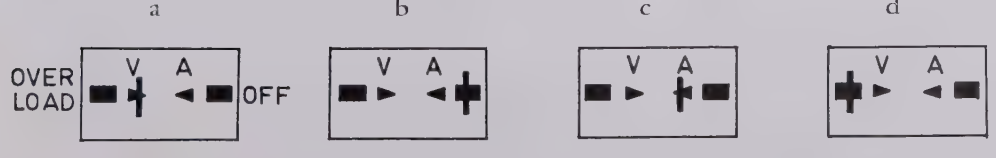


Fig. 6. Mode indicator

at 'OVERLOAD' and the current will remain constant. The max. current values for the various voltage steps are as follows:

Voltage range	Current limitation at 'OVERLOAD'
0... 1 V max. current drain	200 mA) *)
1... 10 V max. „ „	200 mA)
10... 110 V max. „ „	20 mA ~ 30
100...1100 V max. „ „	2 mA ~ 3

For setting and measuring very small currents the electrical zero point can be set by means of potentiometer 'ZERO'. For this purpose the current circuit should be opened (do not remove any leads) and the meter pointer can be set to zero by means of the combined coarse-fine control, R2.
In this way it is possible to compensate for leakage currents up to 1 nA.

4. Reference voltage sources

For the supply of the third and fourth electrode two voltage sources are available, which are continuously adjustable from 0 ... 1 V or from 0 ... 10 V. These supply sources are identical as regards properties and operation and can be adjusted independent of each other. The electrode supply, which can be switched over by means of mode selector SK5, appears from the text plate at the front panel. Normally, the second electrode forms the reference point of supply source. Adjustment of the voltage is effected by preselecting the 0 ... 1 V or 0 ... 10 V voltage range by means of switch SK11 or SK13. Within these ranges the voltage can be adjusted to any intermediate value by means of R4 and R5 respectively.
Reading of the voltage is possible at the meter by depressing the 'READ' button belonging to the supply source (SK10 or SK12).
Full-scale value then corresponds to the preselected voltage range of 1 V or 10 V. Switches SK6 and SK8 serve for changing over the polarity.
By means of step switches SK7 and SK9 it is possible to connect resistors of 0 Ohm... ∞ in series with the voltage sources, also in position 0. Thus the voltage source can be converted into a voltage source with adjustable impedance. This facility permits of accurately examining the break-down range between I_{CEO}, I_{CER} and I_{CEX}.

5. Adjusting the integration time

(For measurements with CURRENT CONTROL)
For deviating loads, such as long leads which are sensitive to hum, high capacitive leads or very strongly non linear test objects it may be advantageous to increase the integration time of the measuring amplifier.
For this purpose an adjusting potentiometer (R517) has been provided, which can be operated with the aid of the knurled wheel by means of a small object (screwdriver, pencil) through the aperture in the right-hand side panel. This control permits of adjusting a suitable integration time that can be varied from approx. 0 (red mark) to slow.
Too high an integration time will cause a reduced response time of the measuring amplifier and consequently control-fluctuations. It is therefore advisable to use a short integration time (red mark on the edge of the potentiometer wheel visible).
The degree of integration is indicated on the indicator whose pointer should be at range 'A'.
For charging capacitors (electrolytic capacitors) it is also possible to accelerate the charging process by first setting SK3 to a high current value (R3 turned fully clockwise) and then resetting it to a suitable measuring range at which the current can be read off.
When the test object is affected by hum, the increase of the integration time with R517 is also indicated, as otherwise measuring errors may occur. This can be seen on the indicator, when its pointer remains in the centre position instead of in position 'A'.

E. EXPLANATION OF THE MODES OF OPERATION

1. Leakage current measurements

The measurements of leakage currents of semiconductors with more than two connections require careful consideration of the electrode arrangement of test object in order to avoid errors. An accurate evaluation of the measuring result is only possible when the results are compared with those of the third and fourth electrode. It is also important to know whether the third or fourth electrode is interrupted, short-circuited with respect to the electrodes under test or connected to an external resistance or voltage (polarity!).
For transistors with three connections the following designations are usually employed: e.g. I_{CEO}, V_{CEO}.
The first letter 'I' is the symbol for current and 'V'

*) In this case current control starts at 100mA. Only through the second circuit or in case of a short-circuit between the test electrode and earth, there will be a current of approx. 300 mA.

for voltage. The subscripts have the following meaning:

1st letter: 1st electrode or test electrode e.g.
C = collector
E = emitter
B = base

2nd letter: 2nd electrode or reference electrode for the first electrode, meaning the same as for 1st electrode.

3rd letter: 3rd electrode (not indicated), which may be used for an external component.
For this the following designations are usually employed:
O = open-circuited (not connected)
R = resistor between 3rd and reference electrode
S = short-circuit between 3rd and reference electrode
X = voltage source + R between 3rd and reference electrode.

For the PM 6509 the letter 'S' has been used for the fourth electrode. This is derived from the term 'screen' which was previously used, but it may also mean substrate, body or casing. The relationship between the third electrode and the test junction when connected to O, R, S or X is shown in the curves of Fig. 7. Fundamentally, the leakage current measurement should take place at a certain voltage, to be selected or indicated by the manufacturer. The value of this voltage, in turn, depends on the circuit connected to the third electrode, which shows that the voltage break-down may differ, dependent on the connection method (also see under point 2, break-down measurements).

2. Break-down voltage measurement

The measurement of the break-down voltage BV is closely related to the leakage current measurement; therefore this chapter forms a supplement to point 1. As opposed to leakage current measurements the measurement of break-down voltages takes place at a constant current, which depends on the semi-conductor under test or which is indicated by the manufacturer. This current may lie in the order of magnitude of the leakage current but may also be considerably higher, dependent on the type and application of the semi-conductor.
The two reference voltage generators with arrangement possibilities for voltage, current or resistance or for open circuited or short-circuited junctions, permit of most types of measurements occuring in practice.
The break-down range can therefore be examined in detail between I_{CEO} and I_{CEX}, without necessitating the use of additional auxiliaries.
Operation of the PM 6509 for break-down voltage measurements is very simple, and the facility to preset

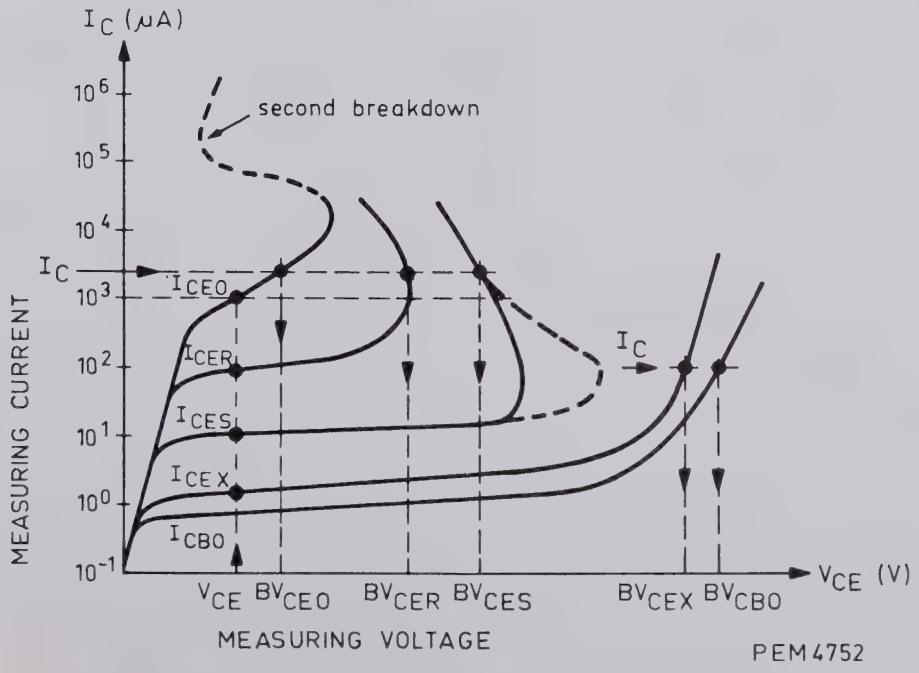


Fig. 7. Leakage current and breakdown voltage

a current of a certain value ensures that the test object is not damaged.
The only point that should be observed is that the test object is not damaged by load surges (see V.C. 1). For this reason it is recommended to start at a low current and voltage setting. When the instrument indicates the desired current value (the indicator pointer should be at 'A', i.e. current-controlled supply) the meter button may be depressed so that the voltage value can be read on the meter.
Similar to break-down voltage measurements to transistors and diodes, it is also possible to measure voltages in certain well-defined applications, such as e.g. ignition or burning voltages of zener diodes, charges of capacitors etc.
The max. current values referred to the voltage ranges appear from the technical data. The voltage measuring range extends from 0.1 ... 1000 V.

3. Measuring certain parameters by means of the reference voltage sources

The method of loading the 3rd and 4th electrode by means of the switchable auxiliary voltage sources permits of a large number of measuring arrangements. The internal switch SK15 permits of changing over from 'NORMAL' to 'GROUNDED' so that the number of possibilities is further extended.
It is also possible to effect h_{FE} measurements, slope measurements of FET transistors, drain current measurements as a function of the gate voltage, knee voltage measurements, measurement of the residual resistance in closed transistor circuits etc. The last part of this manual gives a number of examples of such measurements.

4. Resistance measurements

The combined current or voltage-controlled supply in principle enables two different types of resistance measurements, viz.:

a. Measuring the current at constant voltage. The resistance value then equals the reciprocal of the current and should be converted, or,

b. Measuring the voltage at constant current. The resistance value then equals the voltage and is direct reading in Ohms on the scale.

The most convential and easiest method for the PM 6509 is that mentioned under **b**. For this method the measuring range extends from 1 Ohm ... 10 T-Ohms. The method mentioned under **a**, however, permits of measurements up to 100 T-Ohms, so that it may also be necessary to apply this method.
As resistance measurements of this order of magnitude are very rare, the method mentioned under **b** will usually suffice. In the following table the measuring ranges for the application as Teraohmmeter with linear scale (constant-current operation) are given.

		CURRENT RANGE										
		100 pA	1 nA	10 nA	100 nA	1 μA	10 μA	100 μA	1 mA	10 mA	100 mA	
VOLTAGE RANGE	0.1 - 1 V	1 - 10G	0.1 - 1G	10 - 100M	1 - 10M	100k - 1M	10 - 100k	1 - 10k	100 - 1k	10 - 100	1 - 10	Ω
	1 - 10 V	10 - 100G	1 - 10G	0.1 - 1G	10 - 100M	1 - 10M	100k - 1M	10 - 100k	1 - 10k	100 - 1k	10 - 100	Ω
	10 - 100 V	0.1 - 1T	10 - 100G	1 - 10G	0.1 - 1G	10 - 100M	1 - 10M	100k - 1M	10 - 100k	1 - 10k		Ω
	100 - 1000 V	1 - 10T	0.1 - 1T	10 - 100G	1 - 10G	0.1 - 1G	10 - 100M	1 - 10M	100k - 1M			Ω

From this table it appears that most resistance values can be measured in several voltage ranges or current ranges. This facility permits of adapting the test object to the type of measurement. The measurement can then take place at minimum voltage or at minimum current without the measuring accuracy being affected. At the same time the voltage dependence of the test object can then be examined. Such an adaptation is very advantageous in many cases, e.g. in the case of a semi-conductor whose break-down voltage may not be exceeded. Measurements according to **a**, with constant voltage supply and reciprocal scale value should be effected as follows:

- Voltage adjustment, 1000 V (100 V, 10 V, 1 V)
- Connect resistance to test junction (connect 1st and 2nd electrode).
- Set SK3 to such a range value, that the meter shows a deflection which lies within the selected range (the meter button should not be depressed).
- A reading of e.g. 10, at range step 0.1 nA of SK3, then gives the following resistance:

$$R = \frac{1000\ V}{10.\ 10^{-12}A} = 100\ \text{Teraohm} = 10^{14}\ \text{Ohm}$$

(10 pA) (at 10% deflection)

(At the lowest current ranges the zero point of the meter and sometimes leakage currents of cables or test components should be observed, also see VI.D. 3.b).

5. Current measurements

The PM 6509 can also be used as a highly sensitive current measuring instrument, whose measuring range extends from 1 pA (1% of f.s.d.) to 100 mA.

Measuring connections:

For external current measurements connection is effected to the 2nd electrode and socket ⏚. With respect to sockets BU3...5 of SK5, that socket should be employed whose letter corresponds to the 2nd electrode for the type of measurement applied e.g. in position I_{CE} connection to E and ⏚, in position I_{ES} connection to S and ⏚.
Voltage range selector SK2 should be set to 0, the polarity of the current direction can, if necessary, be reversed by means of buttons NPN/PNP. When the + is connected to ⏚ (BU1), button PNP (–) should be depressed.
Selection of the measuring range is effected with SK3, meter button released. For zero setting the measuring-circuit should be open, SK3 should be set to .1 nA and the meter pointer should be set to 0 by means of potentiometer ZERO (R2).
By means of potentiometer R517 at the side panel the integration time can be adjusted. From output voltages 3...4 V the picoammeter has a very strong non-linear limitation, so that even very high overloads (factor 10^2 up to 10^6) will not damage the circuitry at the lowest ranges.

6. External outputs

At the rear of the PM 6509 a multi-pole socket connector has been provided which serves for the connection of external control, measuring or recording equipment (Fig. 8). At this socket connector the stabilised auxiliary voltages of +15 V and –15 V with respect to earth are also available for external use (max. current 50 mA).
This gives the following possibilities for external measurement or control:

- Recorder output for voltage measurement
- Recorder output for current measurement
- External switching of the test voltage circuit
- External control of the test voltage
- External control of the test current

Socket arrangement

a. Recorder output for voltage measurement

At sockets D and E of socket connector BU7 a current is available which is proportional to the voltage at the test object (1st and 2nd electrode).
When the 'METER' button (SK1C) is depressed, the voltage at sockets D and E is 350 mV at f.s.d. (100) of the meter.
When the 'METER' button is released the current in the same measuring circuit is 350 μA. The requirement is, however, that the terminating resistance at sockets D and E is 1 kOhm $\pm$ 1%. The internal resistance of the recording or measuring equipment to be employed should therefore be observed and if necessary be completed to 1 kOhm by means of series or shunt resistors.
The output voltage or output current for connection of a recorder is proportional to the indication of the meter, independent of the range selected with SK2.

b. Recorder output for current measurements

For external current measurements by means of a recording instrument or digital voltmeter a voltage is

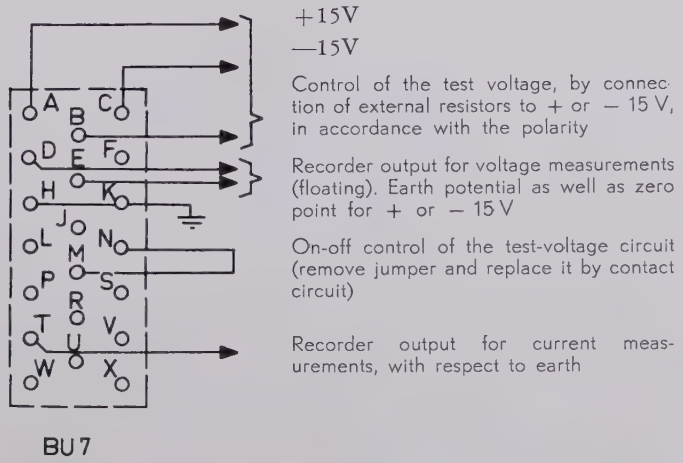


Fig. 8. Multipole socket connector

available at sockets T with respect to H/K which is proportional to the current flowing through the test object. This voltage is 1 V at f.s.d. (100) of the meter, independent of the range selected with SK3. The minimum load resistance of either the recording or measuring instrument should be 1 kOhm.

c. External control of the test voltage circuit

When using the measuring instrument in inspection lines and in the case of automatic switching of the test object it is important that the full test voltage is not applied to the test object. Voltage surges caused by load variations will damage the test object when this is connected direct to the test circuit.
The special voltage control facility of the PM 6509 permits of voltage control via an external switching circuit, so that the voltage increases from zero up to the nominal value for each new measurement. Due to this gradual load increase load surges at the test object are avoided.
The switching circuit can be externally connected to sockets M and N of BU7; the internal jumper of the socket connector should then be removed.
As soon as this current circuit is interrupted, the voltage will drop to 0 (time constant, see VI.D.1) and when the circuit is closed the voltage increases again until the required value is reached. This charging/discharging phenomenon requires a certain time which depends on the voltage value, and should be taken into account (also see under VI.D.1).

d. External control of the test voltage

The test voltage at the first and second electrode can be controlled by means of external resistors which should be connected to sockets 'B' and 'A' or 'C' of BU7.
Within the preset range of SK2, an arbitrary test voltage can be selected in accordance with the reference resistor included. The resistance values are proportional for all volt ranges, so that a certain resistance value gives practically the same pointer deflection at every voltage range. The value of the reference resistance is reciprocal with respect to the voltage value. For a voltage of 110% of an arbitrary measuring range a resistor of e.g. approx. 40.8 kOhm is required and for 11% of the deflection range approx. 800 kOhm. In the case of external control voltage control R1 should be at min., i.e. turned fully anti-clockwise, otherwise the external control is influenced by R1.
Selection of the test voltage polarity is effected with push buttons NPN (+) / PNP (–). Dependent on the polarity the circuit for external voltage control should be connected to –15 V (socket C) in case of NPN or +15 V (socket A) in the case of PNP, so that the amplifier is correctly driven.
When the potential on the first electrode should be positive e.g., button NPN should be depressed; the external voltage control should then be effected with a resistance circuit connected between socket 'B' and socket 'C' (–15 V).
When the polarity on the test electrode is different, connection should be effected to socket 'A' (+ 15 V).

e. External control of the test current

For external control of the current in the test circuit connection should be effected to sockets BU3...6 and BU1. For this two arrangements are possible, whose working principle is the same, but which results in inverse functioning of the current control circuit due to the reverse polarity of the auxiliary voltage. The principles of these circuits are shown in Fig. 9.
Connection of the external reference current source is effected to the 2nd electrode and to the earth socket.
The example shown in Fig. 9, corresponds to position I_{CE} of SK5.

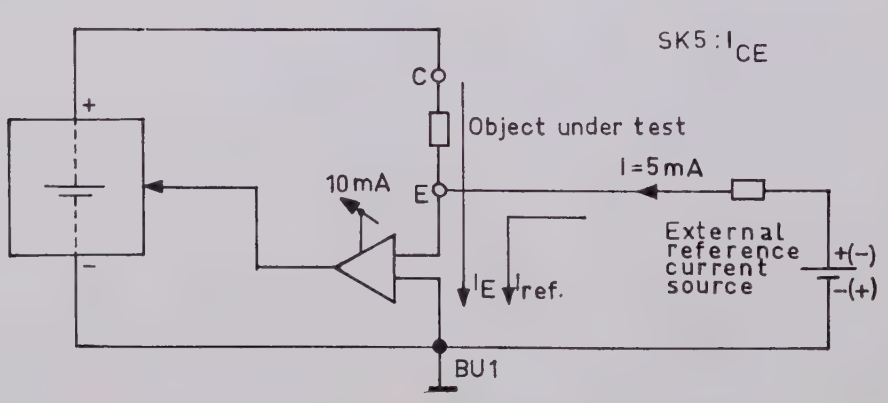


Fig. 9. External control of the test unit

From the supply source the test current flows to 'E', via C and the test object and then via the amplifier – measuring circuit to ⏚, and back to the supply source. The amplifier controls the supply source so that a preset current flows through the test object, e.g. 10 mA. In our example the measuring circuit is connected between E and '⏚'. It is possible to influence the measuring circuit by applying an external current. In this case the amplifier will respond so that the control signal assumes a value corresponding to a test current of 10 mA. Due to this external influencing of the measuring current circuit, a value is obtained for the test current which no longer corresponds to the original required value.

Dependent on the polarity of the external control current applied the amplifier will increase or reduce the current in the test object, which results in both control methods. In our example the test current preselected with SK3 is 10 mA. By means of an external current source a current of, for example, 5 mA is applied to the measuring circuit. In theory there will be a current of 15 mA through the measuring circuit at the first moment.

However, the amplifier will then influence the measuring circuit so that the current becomes 10 mA again. For this purpose it should control the supply source so that the voltage at the test object is reduced by a half, so that a current of 10 mA is obtained in the measuring circuit. In reality however, the current in the test object will then be 10 – 5 = 5 mA.

If the control current has the reverse polarity the theoretical current through the measuring circuit would have been 10 – 5 = 5mA. However, the amplifier regulates this current again to 10 mA. The voltage at the test object then becomes 1.5 times as high, so that the current will then be 15 mA.

7. Changing over the measuring system from common reference electrode to isolated circuit with earthed auxiliary voltage

It is possible to change over the common point of the two auxiliary voltages from the normal electrode arrangement with three supply sources. Normally the 2nd electrode is the reference point of the two auxiliary voltages. With a switch (SK15) the common point can be switched over from the 2nd electrode to earth potential. This switch can be operated through a hole in the bottom panel by means of a rod-shaped object (small screwdriver or pencil).

The 3rd and 4th electrode are both supplied with respect to the reference electrode in position 'NORMAL' (Fig. 10) and in position 'GROUNDED' they

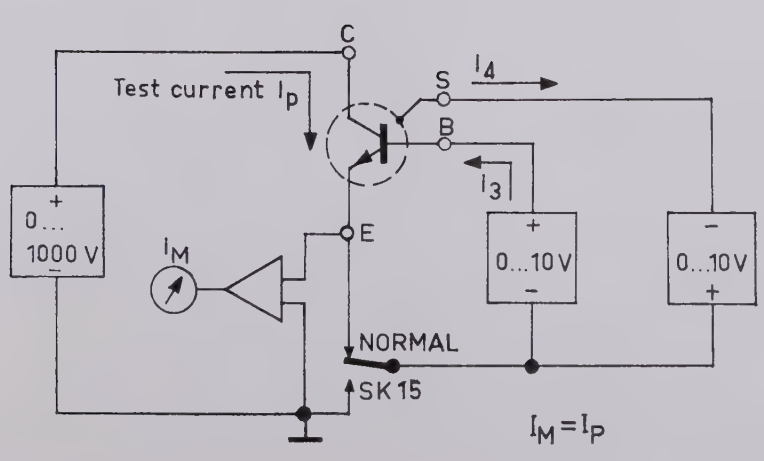


Fig. 10. Position NORMAL

are supplied via earth and the measuring circuit (Fig. 11).
The figures show the current path with respect to the measuring circuit. These two arrangements make it possible to carry out measurements in which the test junction is influenced or depends on the load of the 3rd or 4th electrode. Switch position 'GROUNDED' is therefore very suitable for measuring current gains h_{FE} at small base currents.

h_{FE}-Measurement

This measurement will be dealt with in furhter detail because there exist certain relations which may greatly simplify the measurement. The circuit diagram of this mode of operation is shown in Fig. 12. The base emitter junction of the semi-conductor under test is connected to the test electrode circuit (1st and 2nd electrode) and is supplied by a constant current, e.g. 1 nA. A resistor R_E should be connected in series with the emitter connection; this resistor determines the constant base current. The collector circuit should be connected to the reference voltage source 0...1 V, 0...10 V or a circuit resistor (SK7, R4 and SK11).
The base-emitter circuit and the collector-base circuit have the following relationship.

$$h_{FE} = \frac{I_C}{I_B} = \frac{I_E - I_B}{I_B} = \sim \frac{I_B}{I_E}$$

(When I_B is constant)

$$h_{FE} = \text{constant K. } I_E \text{ or}$$

$$h_{FE} = \frac{K.\,(Vp - V_{EB})}{R_E} = \sim K'.\,Vp$$

When V_p is considerably higher than V_{BE} the formula in brackets may be simplified and may be seen as I_E.

The current gain h_{FE} is consequently proportional to test voltage V_p.

Example 1. $RE_{MF} = 1$ MOhm
(applied constant base current $I_B = 1\ \mu A$)
Range $V_p = 100$ V
Reading $V_p = 80$ V

$$I_E = \frac{80\text{ V}}{1\text{ MOhm}} = 80\ \mu A$$

$$h_{FE} = \frac{80\ \mu A}{1\ \mu A} = 80$$

(A reading of $V_p = 95$ gives accordingly a h_{FE} of 95)

Example 2. $R_E = 10$ GOhm
$I_B = 1$ nA (applied constant base current)

Range $V_p = 100$ V Reading $V_p = 63$ V

$$I_E = \frac{63\text{ V}}{10\text{ GOhm}} = 6.3\text{ nA}$$

$$h_{FE} = \frac{6.3\text{ nA}}{1\text{ nA}} = 6.3$$

A reading of e.g. $V_p = 87$ gives accordingly a h_{FE} of 8.7

The external resistor R_E for measuring the base current at different current values I_E is given in the following table.

I_E	R_E	V_p
10 nA	10 GOhm	100 V
100 nA	1 GOhm	100 V
1 µA	100 MOhm	100 V
10 µA	10 MOhm	100 V
100 µA	1 MOhm	100 V
1 mA	100 KOhm	100 V

Measurement with constant base current

The following instructions pertain to an NPN transistor.

- Set switch SK15 to 'GROUNDED' (at the bottom of the instrument).
- Set switch SK5 to I_{EB}.
- Connect the collector and base of the semi-conductor under test to sockets C and B, and connect the emitter to socket E via resistor R_E (the value of this resistor should be in accordance with the desired base current, as indicated in the above table; in this example 1 MOhm).
- Depress button PNP (–to emitter).
- Set switch SK6 to + (for NPN transistor).
- Set switch SK7 to 0.
- Set switch SK11 to 10 V.
- Turn voltage control R4 fully clockwise.
- Depress button 'METER' (SK1C).
- Set switch SK2 to 100 V and turn R1 fully clockwise; SK3 should be set to such a range (1 µA) that the current limiter becomes operative (indicator at 'A'); turn R3 fully clockwise.
- Now read the voltage on the instrument.
- The h_{FE}-value can be directly read (e.g. a voltage reading of 48 V corresponds to a current gain h_{FE} of 48 at a constant base current of 1 µA).

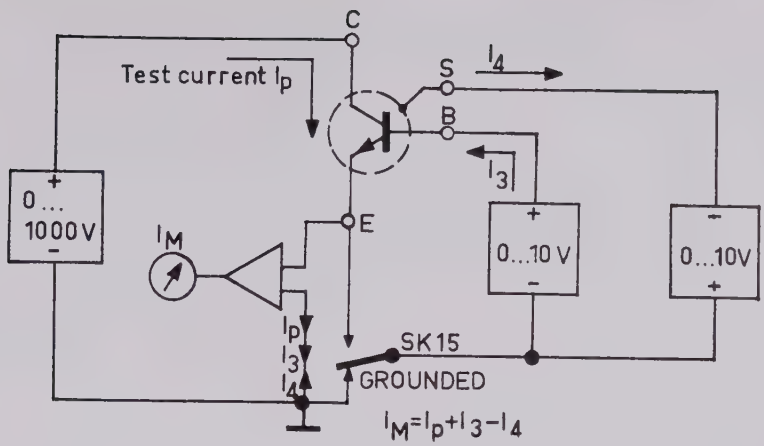


Fig. 11. Position GROUNDED

Measurement with constant emitter current

With these measurements the emitter current is set to a constant value by applying a stabilised voltage (V_p) to the series resistor in the emitter circuit.
E.g. V_p = 100 V and R_E = 1 MOhm gives 100 μA.
In this case the current limiter should not become operative (indicator at 'V').
When the base current is read now with released 'METER' button – e.g. 2 μA – the current gain follows from:

$$h_{FE} = \frac{100\ V/1\ MOhm}{2\ \mu A} = 50$$ (at a constant emitter current of 100 μA)

Possible deviations between the two modes will be due to the characteristic of the semi-conductor under test. In the first case h_{FE} is measured at an I_B current of 1μA and in the second case at a current of 2 μA, which may result in different measuring values.
By setting SK11, SK7 and R4 accordingly the dependence of h_{FE} on the collector voltage can be examined.

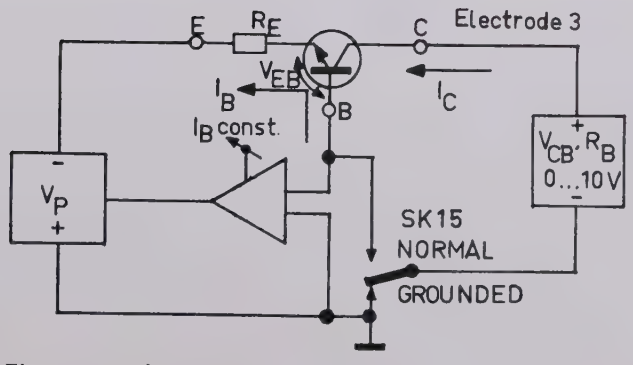
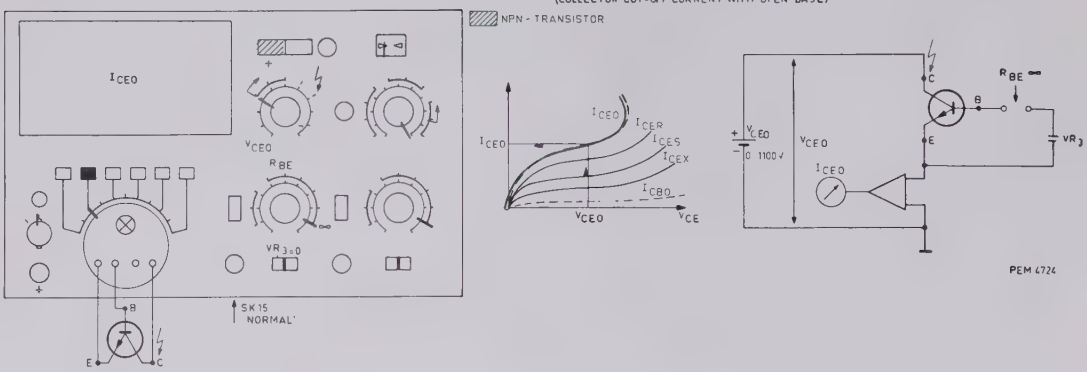


Fig. 12. Fundamental circuit for h_{FE} measurements

Various measuring examples

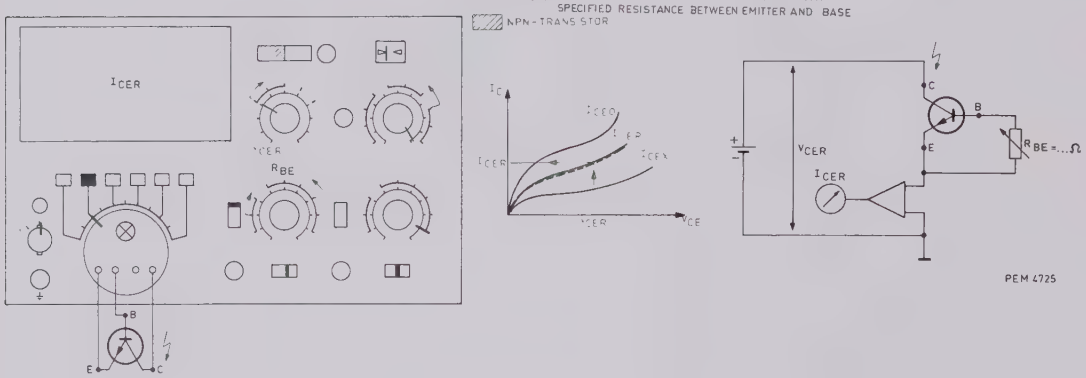
I_{CEO} - COLLECTOR-EMITTER LEAKAGE CURRENT WITH OPEN BASE
(COLLECTOR CUT-OFF CURRENT WITH OPEN BASE)

NPN - TRANSISTOR



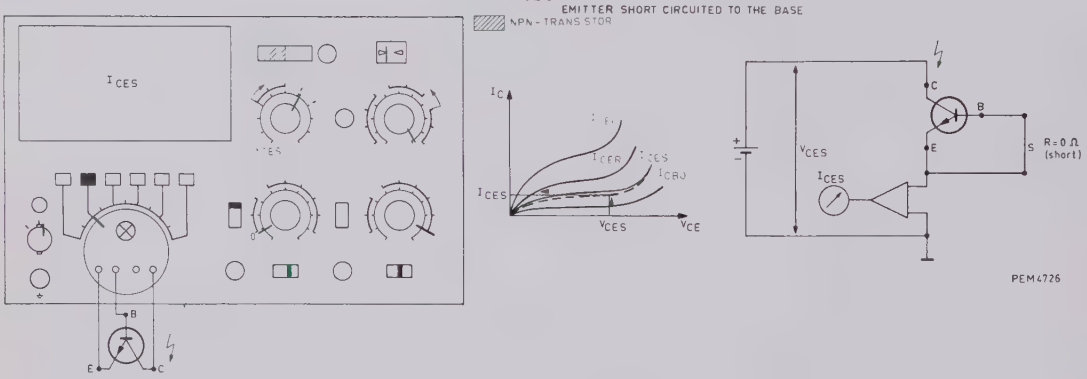
I_{CER} - COLLECTOR-EMITTER LEAKAGE CURRENT WITH SPECIFIED RESISTANCE BETWEEN EMITTER AND BASE

NPN - TRANSISTOR



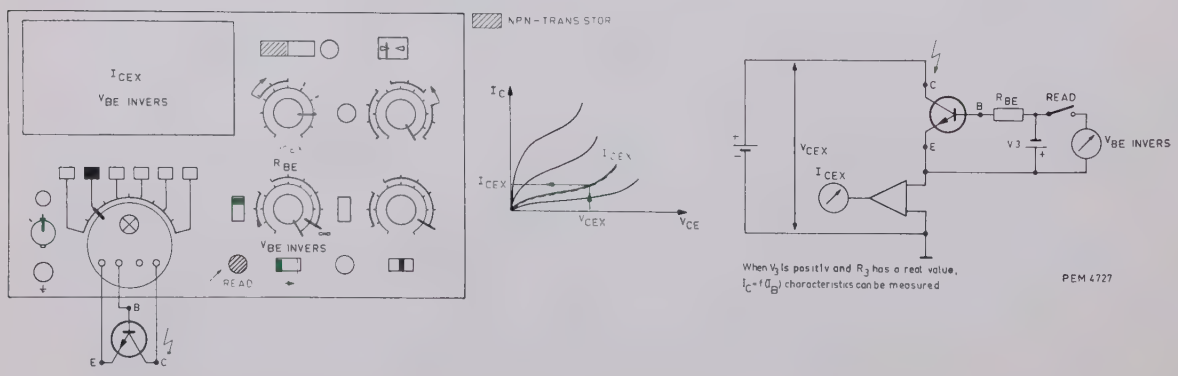
I_{CES} - COLLECTOR-EMITTER LEAKAGE CURRENT WITH THE EMITTER SHORT CIRCUITED TO THE BASE

NPN - TRANSISTOR



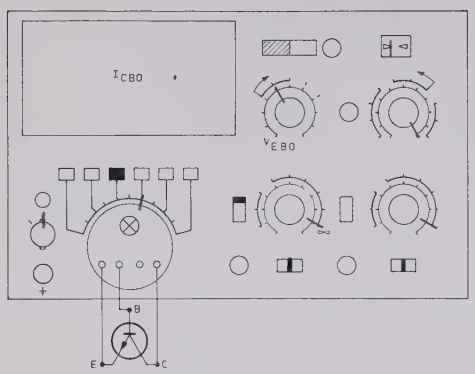
I_{CEX} - COLLECTOR-EMITTER LEAKAGE CURRENT IN A SPECIFIC CIRCUIT

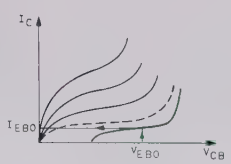
NPN - TRANSISTOR

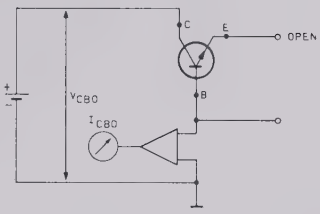


I_{CBO} -COLLECTOR-BASE LEAKAGE CURRENT (COLLECTOR CUT-OFF CURRENT WITH OPEN EMITTER)

NPN-TRANSISTOR





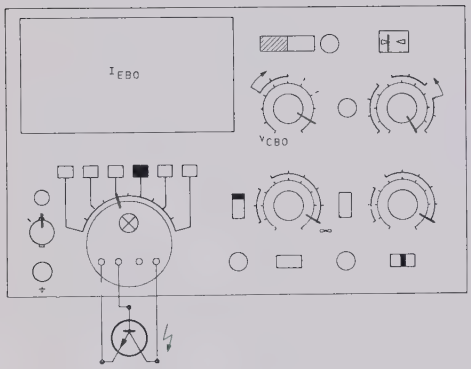


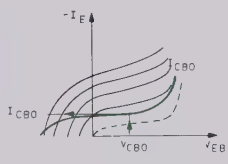
PEM 4728

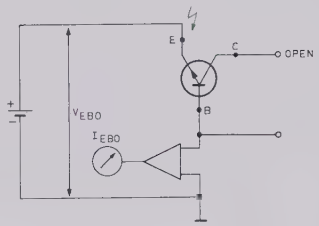
When V_3 is negative and R_3 small, I_E will flow
e common base characteristics

I_{EBO} EMITTER-BASE LEAKAGE CURRENT (EMITTER CUT-OFF CURRENT WITH OPEN COLLECTOR)

NPN-TRANSISTOR





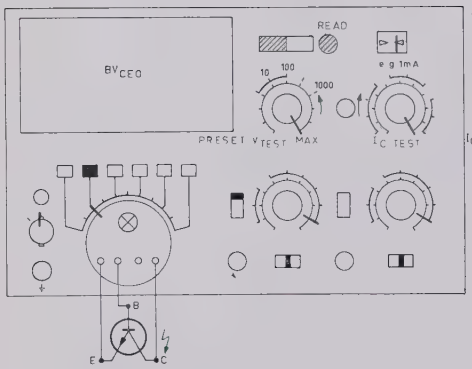


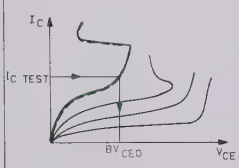
When V_3 is negative and R_3 small, $-I_E$ flows, ie the transistor works in the inverted mode (chopper)

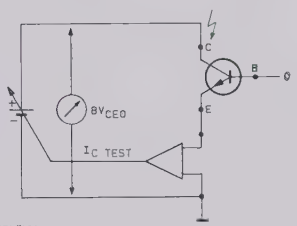
PEM 4729

BV_{CEO} ($V_{(BR)CEO}$)-COLLECTOR-EMITTER BREAKDOWN-VOLTAGE WITH OPEN BASE

NPN-TRANSISTOR





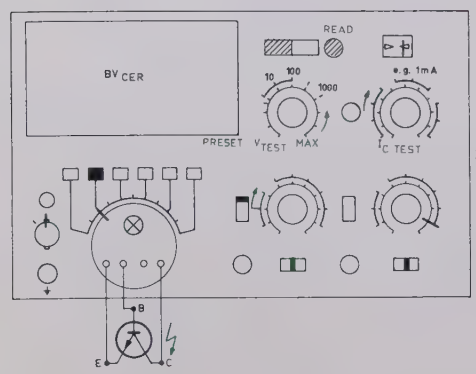


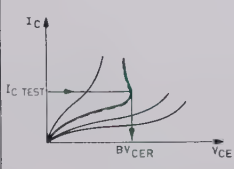
ATTENTION
MIND TEMPERATURE EFFECTS
AND NEGATIVE CHARACTERISTICS

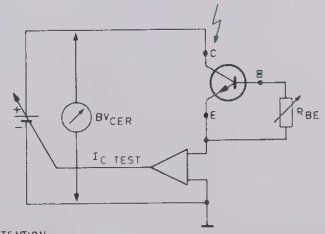
PEM 4730

BV_{CER}-COLLECTOR-EMITTER BREAKDOWN VOLTAGE WITH SPECIFIC RESISTANCE BETWEEN EMITTER AND BASE

NPN-TRANSISTOR



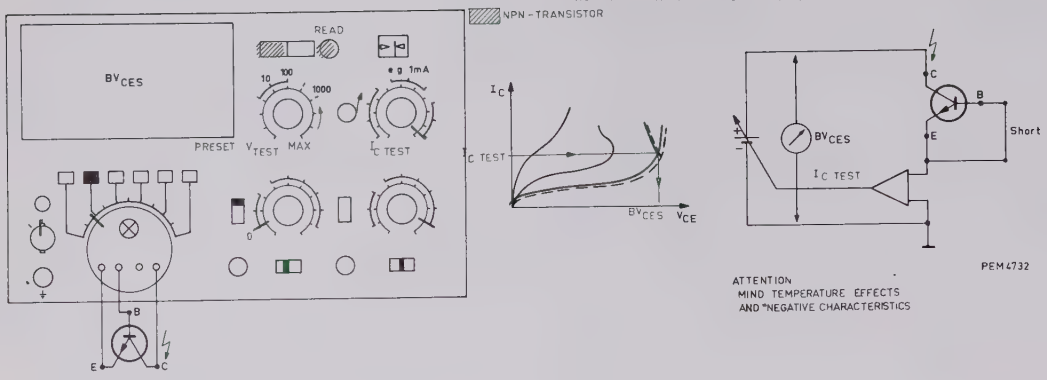




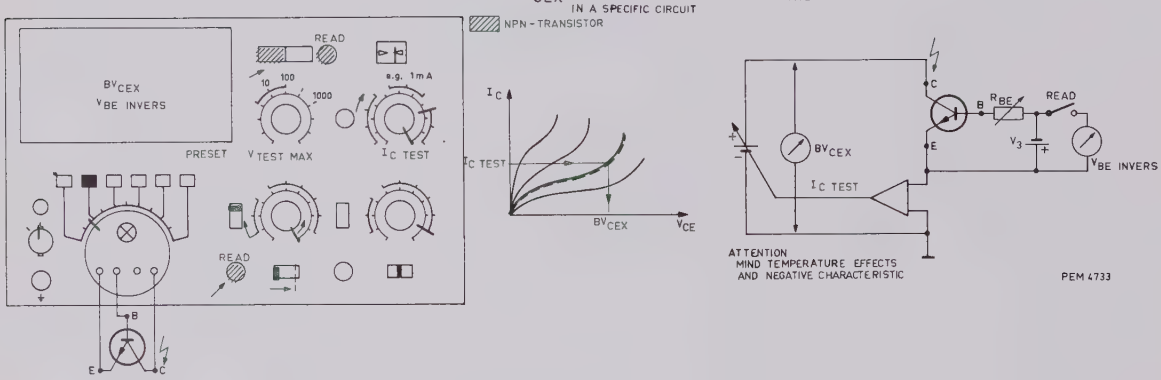
ATTENTION
MIND TEMPERATURE EFFECTS
AND NEGATIVE CHARACTERISTICS

PEM 4731

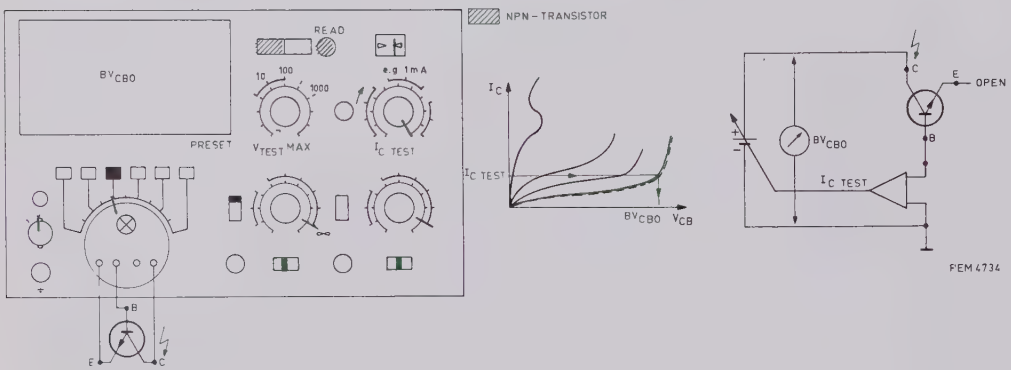
BV_{CES} - COLLECTOR-EMITTER BREAKDOWN-VOLTAGE WITH THE EMITTER SHORT CIRCUITED TO THE BASE



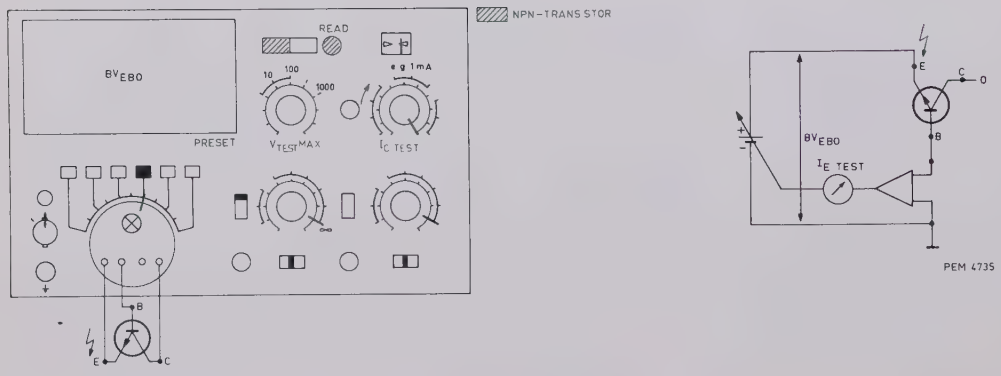
BV_{CEX} - COLLECTOR-EMITTER BREAKDOWN-VOLTAGE IN A SPECIFIC CIRCUIT



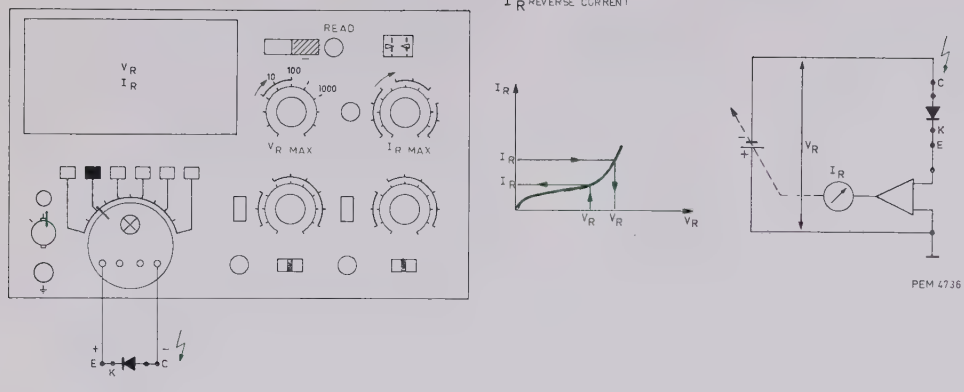
BV_{CBO} - COLLECTOR-BASE BREAKDOWN VOLTAGE



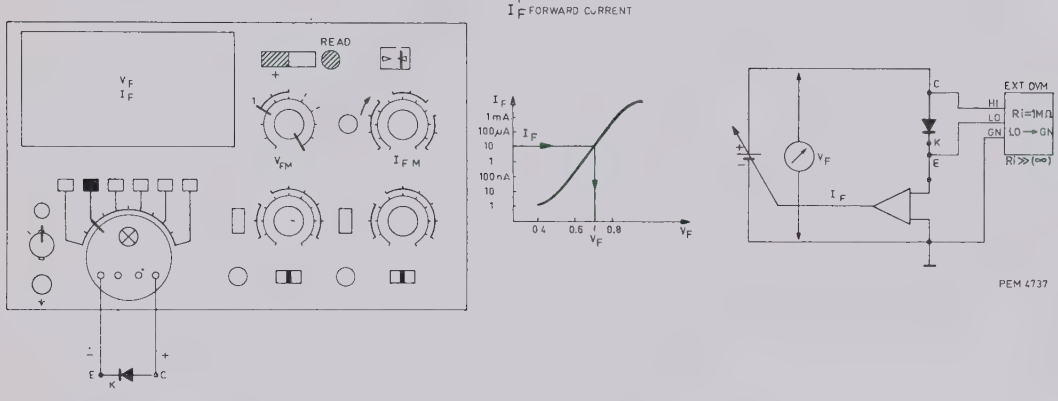
BV_{EBO} - EMITTER-BASE BREAKDOWN-VOLTAGE



V_R REVERSE VOLTAGE
I_R REVERSE CURRENT

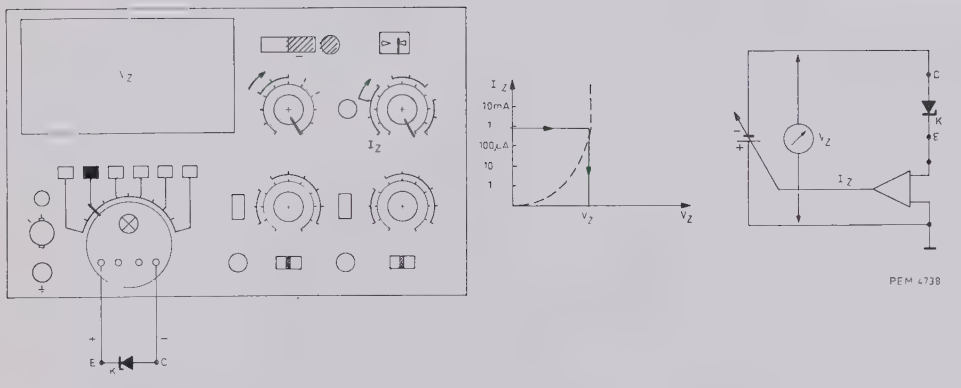


V_F FORWARD VOLTAGE
I_F FORWARD CURRENT

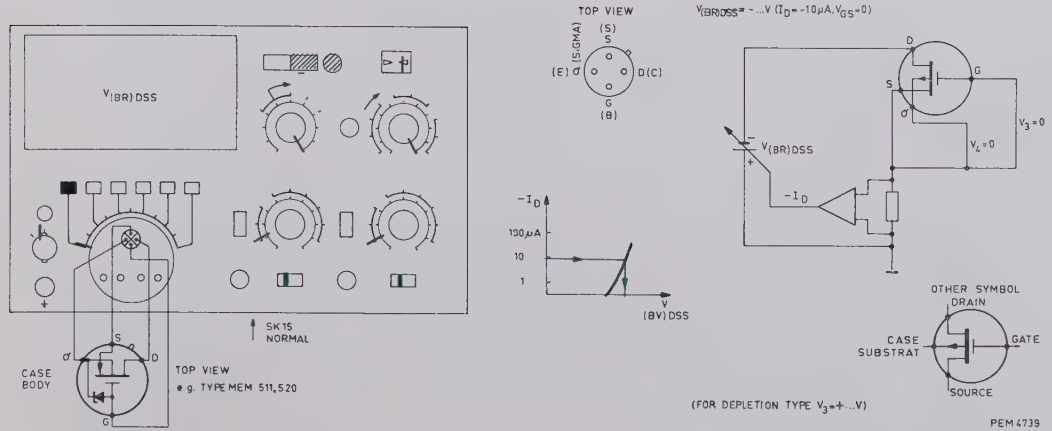


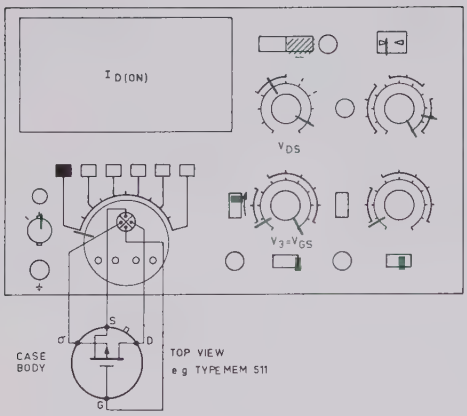
VOLTAGE REGULATOR DIODES (ZENER DIODES)

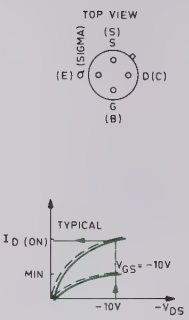
V_Z ZENER VOLTAGE

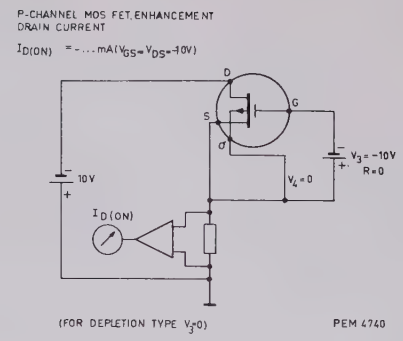


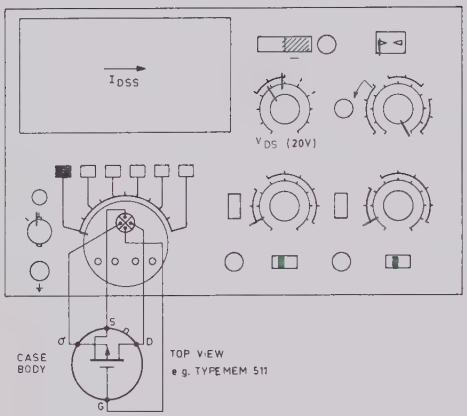
P-CHANNEL MOS FET ENHANCEMENT
DRAIN-SOURCE BREAKDOWN VOLTAGE
$V_{(BR)DSS}$ = -...V (I_D = -10µA, V_{GS} = 0)

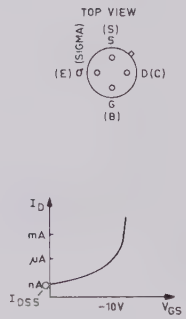


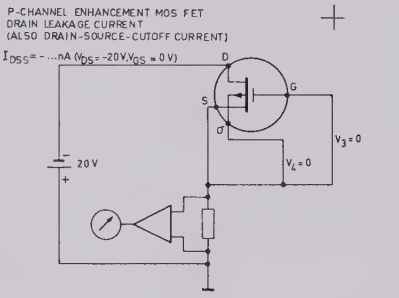

$I_{D(ON)}$
V_{DS}
$V_3=V_{GS}$
CASE
BODY
TOP VIEW
e.g. TYPE MEM 511

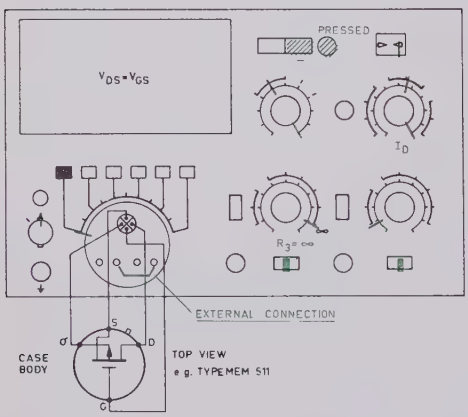

TOP VIEW
(S)
(SIGMA)
(E)
D(C)
G
(B)
TYPICAL
$I_{D(ON)}$
MIN
$V_{GS}=-10V$
$-10V$
$-V_{DS}$

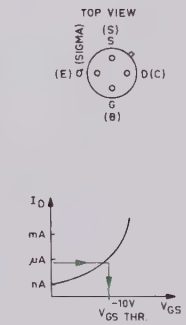

P-CHANNEL MOS FET, ENHANCEMENT
DRAIN CURRENT
$I_{D(ON)}$ = -....mA ($V_{GS}=V_{DS}=-10V$)
D
G
S
10V
$V_3=-10V$
R=0
$V_4=0$
$I_{D(ON)}$
(FOR DEPLETION TYPE $V_3=0$)
PEM 4740

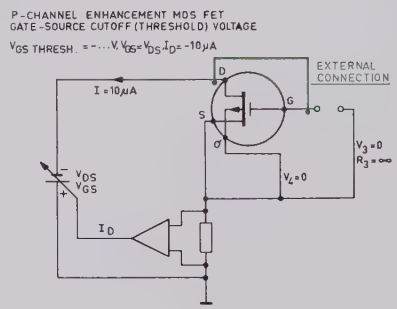

I_{DSS}
V_{DS} (20V)
CASE
BODY
TOP VIEW
e.g. TYPE MEM 511

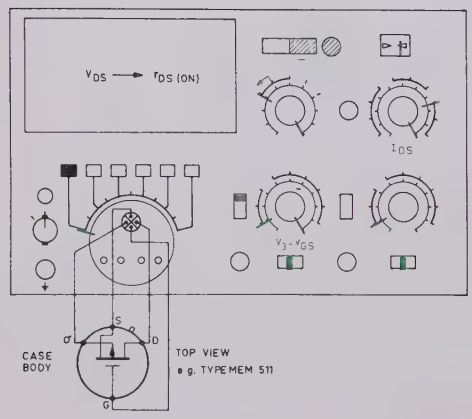

TOP VIEW
(S)
(SIGMA)
(E)
D(C)
G
(B)
I_D
mA
µA
nA
I_{DSS}
$-10V$
V_{GS}

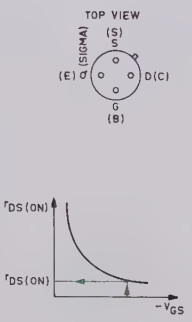

P-CHANNEL ENHANCEMENT MOS FET
DRAIN LEAKAGE CURRENT
(ALSO DRAIN-SOURCE-CUTOFF CURRENT)
I_{DSS} = -....nA ($V_{DS}=-20V, V_{GS}=0V$)
D
G
S
20V
$V_3=0$
$V_4=0$
(FOR DEPLETION TYPE $V_3=+...V$)
PEM 4741

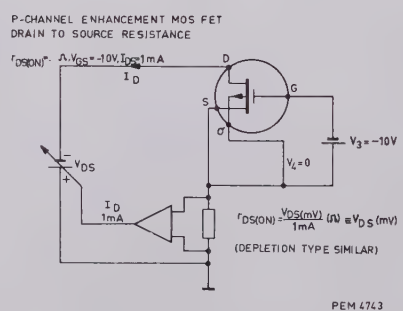

$V_{DS}=V_{GS}$
PRESSED
I_D
$R_3=\infty$
EXTERNAL CONNECTION
CASE
BODY
TOP VIEW
e.g. TYPE MEM 511

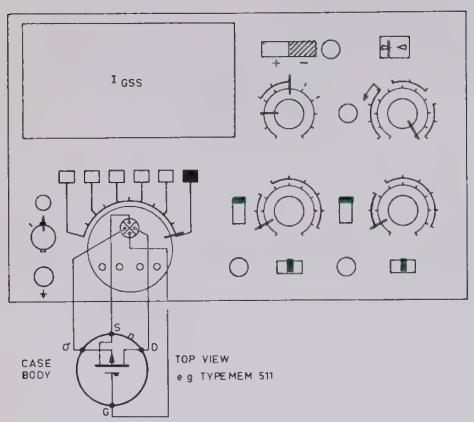

TOP VIEW
(S)
(SIGMA)
(E)
D(C)
G
(B)
I_D
mA
µA
nA
$-10V$
$V_{GS\ THR.}$
V_{GS}


P-CHANNEL ENHANCEMENT MOS FET
GATE-SOURCE CUTOFF (THRESHOLD) VOLTAGE
$V_{GS\ THRESH.}$ = -....V, $V_{GS}=V_{DS}, I_D=-10\mu A$
EXTERNAL CONNECTION
$I=10\mu A$
D
G
S
$V_3=0$
$R_3=\infty$
$V_4=0$
V_{DS}
V_{GS}
I_D
PEM 4742


V_{DS} → $r_{DS\ (ON)}$
I_{DS}
$V_3=V_{GS}$
CASE
BODY
TOP VIEW
e.g. TYPE MEM 511

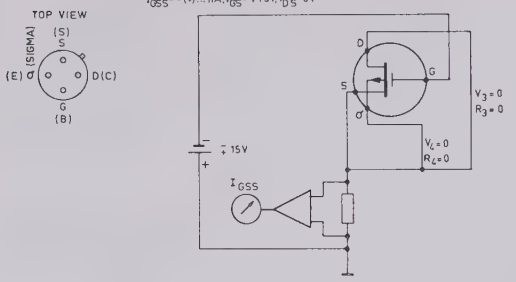

TOP VIEW
(S)
(SIGMA)
(E)
D(C)
G
(B)
$r_{DS(ON)}$
$r_{DS(ON)}$
$-V_{GS}$


P-CHANNEL ENHANCEMENT MOS FET
DRAIN TO SOURCE RESISTANCE
$r_{DS(ON)}$: At $V_{GS}=-10V, I_D=1mA$
I_D
D
G
S
$V_3=-10V$
$V_4=0$
V_{DS}
I_D 1mA
$r_{DS(ON)}=\frac{V_{DS(mV)}}{1mA}(\Omega) \equiv V_{DS}(mV)$
(DEPLETION TYPE SIMILAR)
PEM 4743



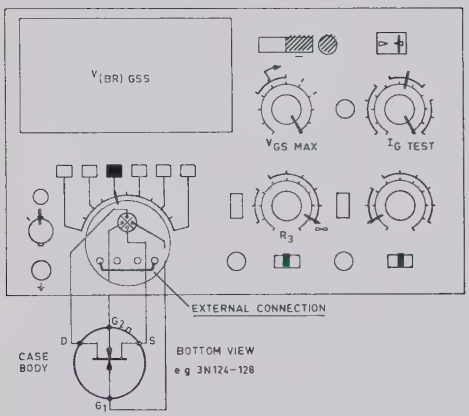
P-CHANNEL ENHANCEMENT MOS FET
DEPLETION TYPE
GATE LEAKAGE CURRENT

I_{GSS} = -(+) .. nA, V_{GS} = ∓15V, V_{DS} = 0V



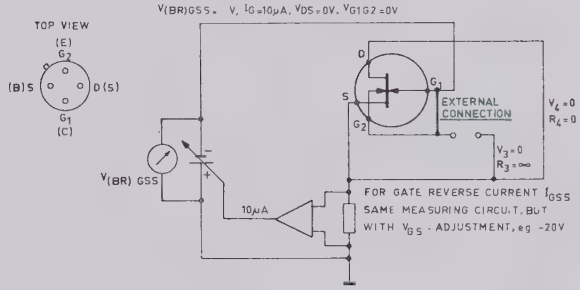
(DEPLETION TYPE SIMILAR)

PEM 4744

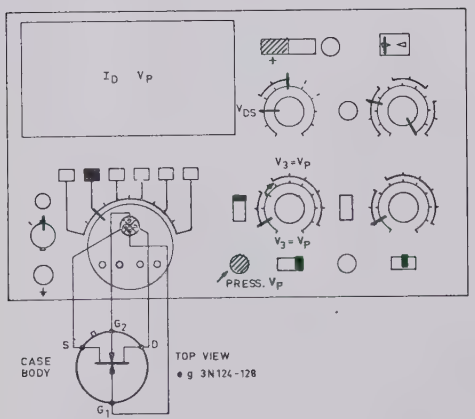


N-CHANNEL JUNCTION FET with 1 or 2 gates
GATE-SOURCE BREAKDOWN VOLTAGE

$V_{(BR)GSS}$ = .. V, I_G = 10µA, V_{DS} = 0V, V_{G1G2} = 0V

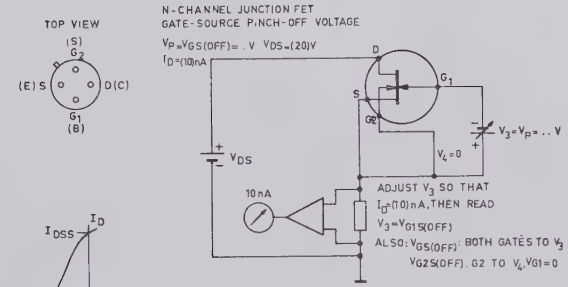


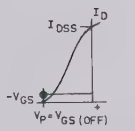
PEM 4745



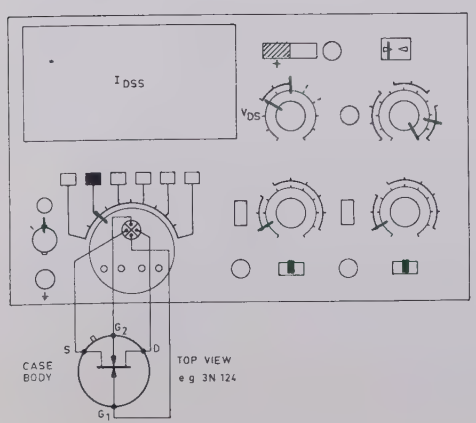
N-CHANNEL JUNCTION FET
GATE-SOURCE PINCH-OFF VOLTAGE

$V_P = V_{GS(OFF)}$ = .. V V_{DS} = (20)V
I_D = (10)nA



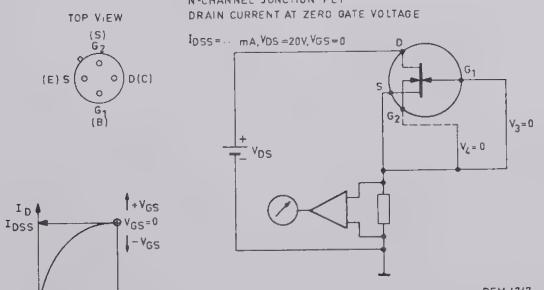


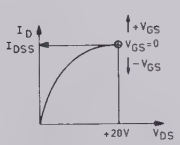
PEM 4746



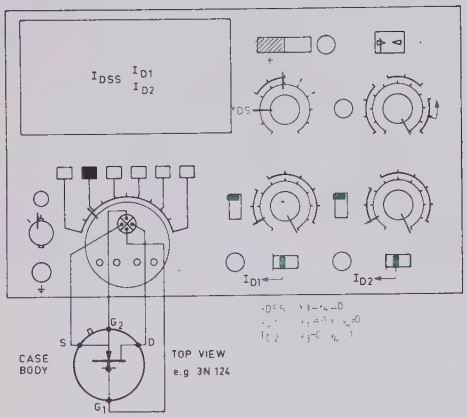
N-CHANNEL JUNCTION FET
DRAIN CURRENT AT ZERO GATE VOLTAGE

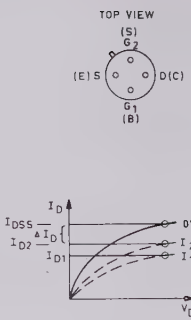
I_{DSS} = .. mA, V_{DS} = 20V, V_{GS} = 0





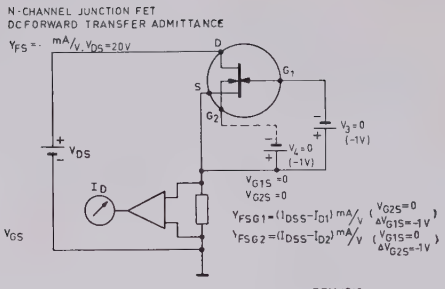
PEM 4747





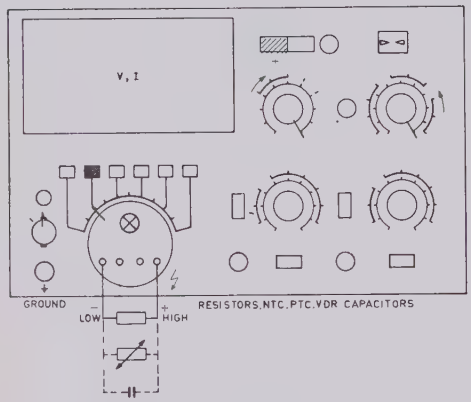
TOP VIEW

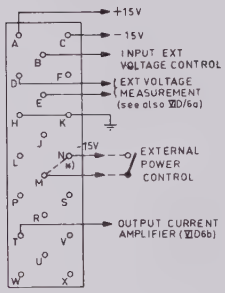
N-CHANNEL JUNCTION FET
DC FORWARD TRANSFER ADMITTANCE

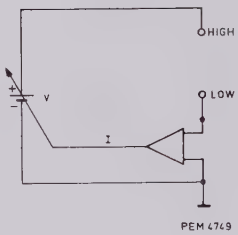


PEM 4748

EXTERNAL CONNECTION

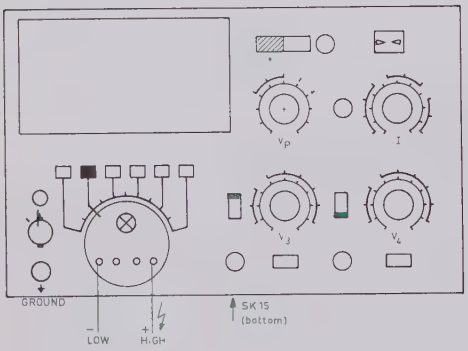




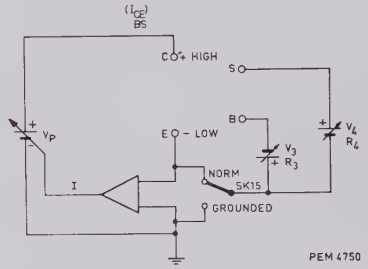


PEM 4749

*) Remove internal connection N-M
N-Potential -15V



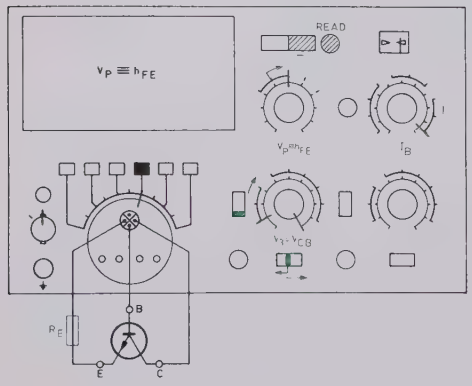
EXTERNAL VOLTAGE SOURCE



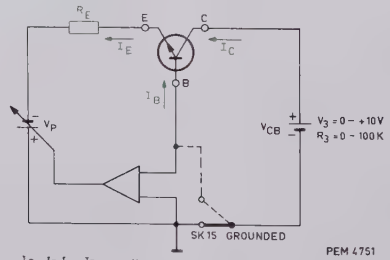
PEM 4750

RANGE	$I_{Pmax.}$	I
1 V	−300 mA	100 mA
10 V	−300 mA	100 mA
100 V	−30 mA	30 mA
1000 V	−3 mA	3 mA

Connection: HI - GROUND HI-LO



h_{FE}
DC CURRENT GAIN
NPN TRANSISTOR



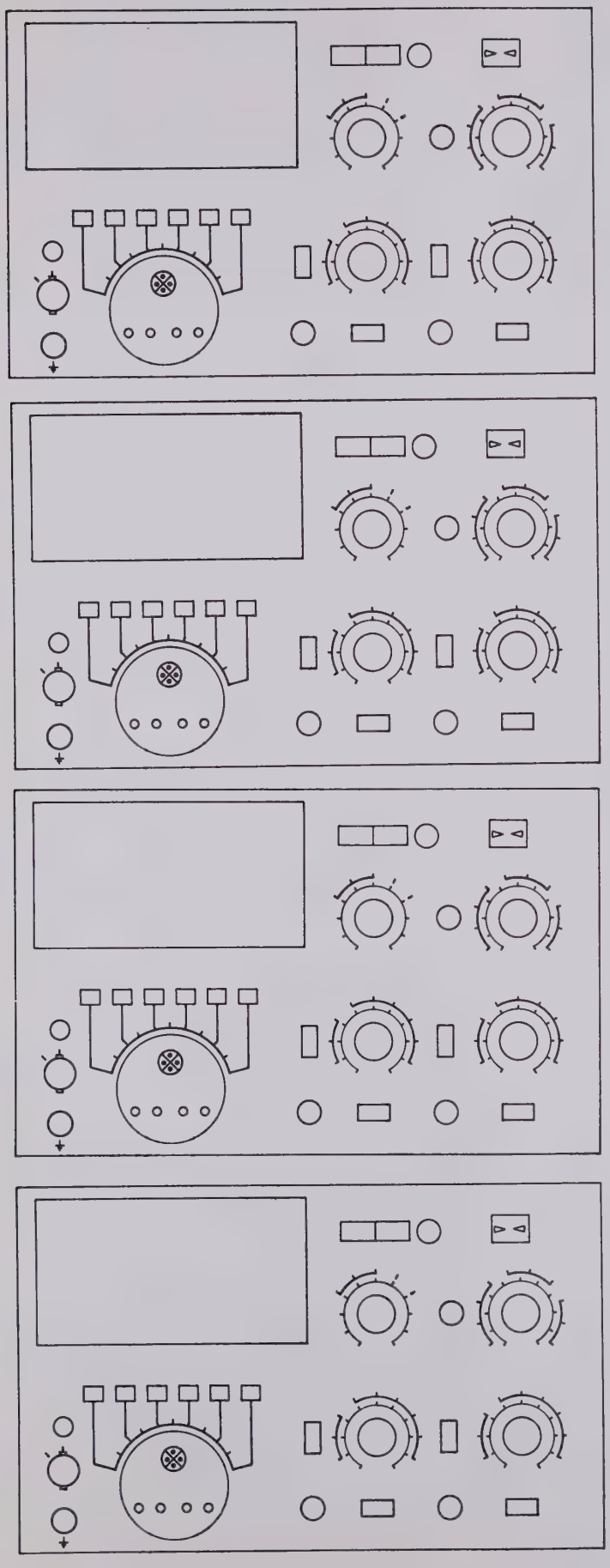
PEM 4751

$h_{FE} = \frac{I_C}{I_B} = \frac{I_E - I_B}{I_B} = \frac{I_E}{I_B}$ $I_E = \frac{V_P}{R_E}$

If I_B is constant, $h_{FE} = k\, I_E = k.V_P$

$k = \frac{1(V)}{R_E(\Omega)\, I_B(A)}$

e.g V_P = 0-100 V, R_E = 1GΩ, I_B = 1nA, $h_{FE} = \frac{1(V)}{10^9(\Omega)\, 10^{-9}(A)} V_P = 1\, V_P$



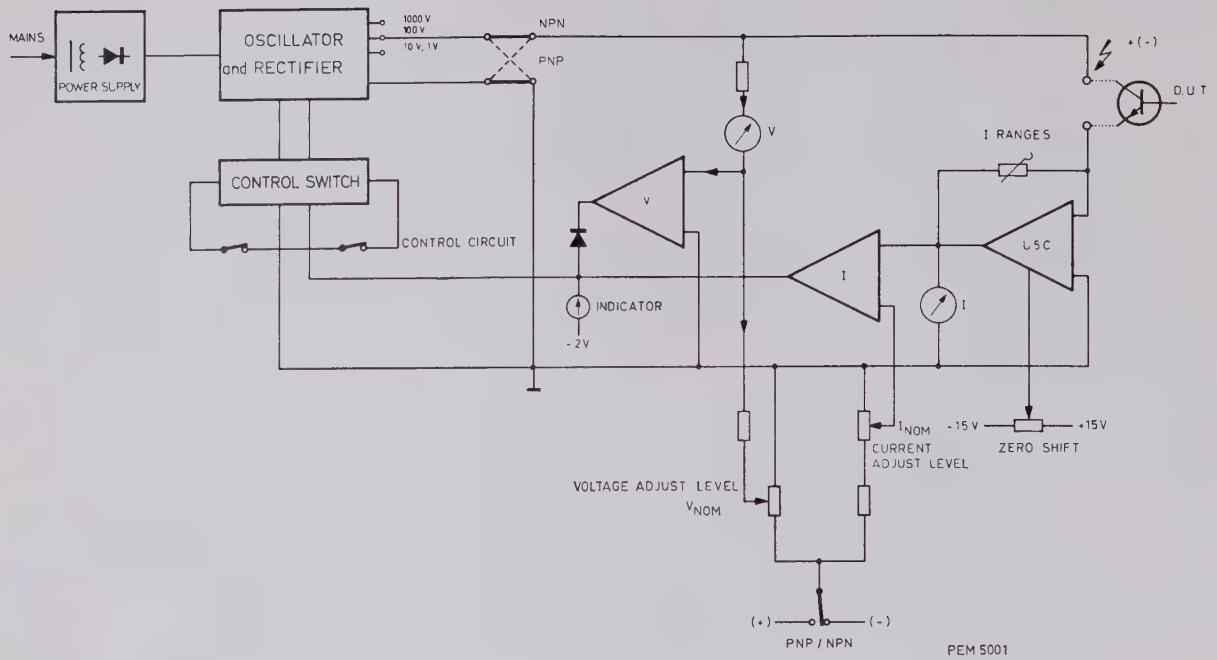


Fig. 13. Working principle of the main test circuit

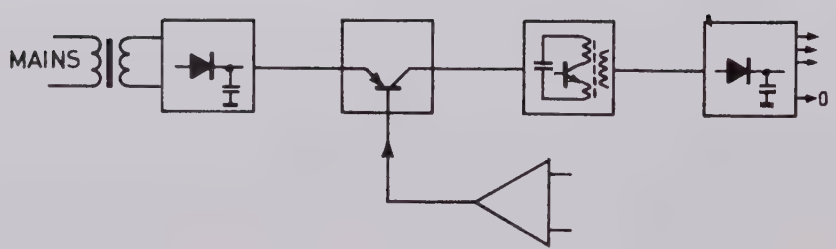


Fig. 14. Generator

SERVICE MANUAL

VII *Circuit description*

A. MAIN TEST CIRCUIT

1. Working principle of the main test circuit

The current and voltage control principle is explained with the aid of the block diagram, Fig. 13.
The direct voltage for supplying the main test circuit is obtained by means of a controlled oscillator. This oscillator comprises a control circuit which determines the amplitude of the output voltage. At the output of the oscillator three different voltages are available, which agree with the voltage ranges of the instrument. The control circuit controls the oscillator in such a way that its output voltage assumes the preset nominal value. When the current limiter is actuated, the voltage is adjusted to a value corresponding to the product of current and resistance.
When the instrument is changed over to a different voltage range or mode of operation, and in the case of external programming, the generator supply voltage should always be raised from 0 or a low value, in order to avoid voltage surges on the semi-conductor under test. This function is performed by the control switch, which affects the control circuit and blocks the oscillator as soon as the safety circuit of the latter is interrupted. The residual charge in the voltage source is drained via internal resistors (mind the time constant!).

Current/voltage control is effected as follows:

The control signals are amplified and matched in two different amplifiers, one for current and one for voltage. The control signals are obtained by comparing the nominal with the actual value. The difference, which may be either positive or negative, controls the oscillator via the amplifiers. The current difference amplifier produces a signal which controls transistor TS303 so that the output voltage causes a current corresponding to the nominal value. This is only the case when the voltage range permits such a current through the load. When the nominal current cannot be reached without the preset voltage being exceeded, the voltage control amplifier prevents a further voltage increase via diode GR305. Thus, the current cannot exceed the value which is governed by the upper voltage limit and the ohmic load of the object under test.
The mutual dependence of current and voltage makes it possible to select either of these quantities, whereby the other quantity can only increase to the preset limit. Thus either the current or voltage is prevented from exceeding the preset value, the criterion being which limit is reached first. The resulting voltage and current can then be read on the moving-coil instrument. The current limitation, which is adjustable over a wide range (5 pA...100 mA) requires a highly sensitive measuring amplifier.
This amplifier is, in principle, an operational amplifier (see point 7); it supplies a control signal until the input signals are equal, i.e. the voltage difference is zero (< 0.1 V). The current ranges are defined by shunts and voltage dividers, which influence the degree of feedback of the measuring amplifier. Within the current ranges the nominal values can be set by means of control R3, which influences the input voltage of difference amplifier I.
An additional control serves for zero-adjustment so that a pre-deflection (due to external influences such as leakage currents etc), can be compensated for and can be adjsted to zero or any other desired value.

2. Generator

The voltage or current required for the semi-conductor under test is supplied by a controlled generator. This generator basically consists of a rectifier, a voltage regulator, a current transformer operating as an oscillator and several output rectifiers and smooting filters (Fig. 14).
Winding S5/S6 of power transformer T1 supplies an alternating voltage of approx. 21 V to Graetz rectifier GR201 (Fig. 47). C201 serves to smooth the pulsating direct voltage. The circuit with TS202 and TS203 is a regulating circuit. The voltage drop across R202 drives the base-emitter junction of TS201, as soon as the voltage exceeds the threshold voltage of GR202. The control current through the base of TS202 is then drained via TS1, thus providing current limitation.

Transistors TS202 and TS203 constitute a Darlington circuit and control the current flow to the oscillator. The control signal is supplied by difference amplifier TS302/TS303, the collector current of TS303 being applied to the base of TS202. As this control signal is practically voltage-independent, a direct voltage with a low hum component will arise at the output of the control circuit across C204.

Oscillator

This oscillator operates as a current transformer. The current through winding S2 is opposite to the current through main winding S1 of T201. The oscillation process is brought about as follows:
At the moment of switching on, a current whose value depends on R204 flows through the base of TS204. The latter transistor becomes conductive, so that an amplified current flows from S1 via the collector-emitter junction of TS204 to S2. The transformed voltage on S2 will drive the transistor further into conduction so that practically the total primary voltage (voltage of C204) is present on S1. This voltage is induced in S3 and is then rectified by GR203... GR206.
As during each discharge period winding S2 produces a current surge, capacitor C202, which is included in the base circuit of TS204, is charged negatively. When the primary current no longer increases, the voltage induced across S2 and S3 will decrease. The transistor is no longer driven and is cut off.; the voltage induced in S2 changes polarity and accellerates the cut-off process. When transistor TS204 is cut off, diodes GR202 – GR206 are also cut off. The energy stored in the magnetic circuit is absorbed as a voltage surge in the primary and secondary circuit, and a new cycle is initiated.
Three different outputs supply the corresponding voltages to the voltage range selector, a separate filter being provided for each voltage range.
By means of the control current on the base of TS202 the amplitude of the oscillator voltage and thus the generator output voltage can be varied.

3. Current and voltage control

a. Current control

The signal for the oscillator is produced in difference amplifier 'I' (Fig. 15). This amplifier consists of transistors TS308 and TS309. The base of TS308 is connected to voltage control R3, by means of which the current limit within a certain measuring range can be set. As voltage control R3 is connected to a constant stabilised voltage (Vnom), the set voltage will form a reference for the difference amplifier. The other input of the difference amplifier, the base of TS309, receives a control signal (V actual), which is obtained from measuring amplifier U5C. Dependent on the current through the semi-conductor under test this operational amplifier produces a control signal for the difference amplifier.

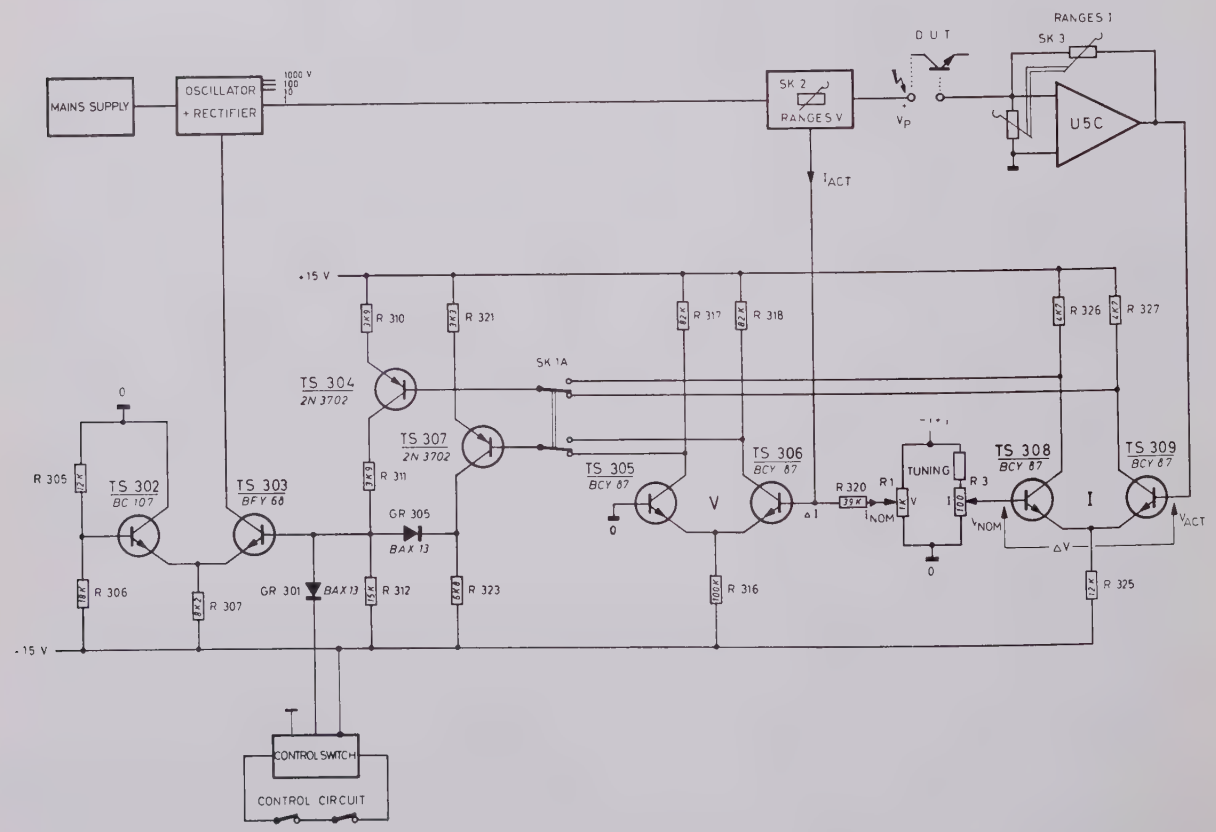


Fig. 15. Voltage and current control

The measuring ranges are determined by means of series and shunt resistors, which alter the feedback circuit of the measuring amplifier. The voltage difference $\triangle V$ then controls the difference amplifier so that an output voltage V_A is attained, which causes a current through the semi-conductor under test in accordance with the preset value. The voltage difference $\triangle V$ is then zero and the system is in the rest condition.

The amplified output signal of the difference amplifier controls TS304 and TS303. The signal on the base of TS303 controls the difference amplifier consisting of TS302 and TS303. This amplifier provides the control signal for the oscillator. Voltage divider R305-R306 supplies the reference voltage for the difference amplifier.

b. Voltage control

The output voltage and the nominal value set with control R1 are compared in the difference amplifier consisting of TS305 and TS306. The current I_{nom}, which is determined by this voltage and resistor R320, is compensated for by the actual current from the range selector and the output voltage. The difference current $\pm \triangle I$ flows through the base of TS306 of the difference amplifier. Thus the control circuit is influenced so that the current becomes zero. As a result I_{nom} will be equal to I actual. R1 then serves as a fine control for the drive signal of TS306, while by means of SK2 the range steps (coarse control) are selected. The output signal of the difference amplifier controls transistor TS307 via polarity switch SK1 A. The latter transistor operates as a voltage amplifier whose current influences the working point of the current control circuit via GR305.

Control process:

When the voltage on the cathode of GR305 is more positive than that on its anode, there will be no current through the diode. The amplifier is then current-controlled and the available voltage range is adequate. At too low a current in the output circuit the voltage on the base of TS303 (anode side of GR305) is less negative than at a higher output current. The oscillator is then controlled so that a higher voltage arises. As soon as the voltage on the cathode side of GR305 becomes more negative than that on the base of TS303 there will be a current through the diode to the -15 V supply. The output current then cannot increase any further, because it is limited by diode GR305. From this point on the amplifier is voltage controlled, because the current now depends on the voltage setting. Only when the voltage is set to a higher value, the controlling process is reversed again. The voltage on the cathode of GR305 then increases and the diode is cut off as soon as the cathode potential is higher than the anode potential. The generator is current controlled as long as the anode potential of GR305 is more negative than the cathode potential. For voltage control the situation is reversed; as long as the diode is conductive voltage control takes place.

4. Protection circuit

When the range selector or mode selector is operated and in the case of external programming, the oscillator should be switched off, in order to prevent transients on the semi-conductor under test which are higher than the preset voltage. For this purpose an electronic control circuit has been included, which cuts off difference amplifier TS302/TS303 as soon as the contact circuit is opened (also briefly), see Fig. 16.

The base of TS301 is connected to the -15 V voltage source via several switch contacts and via short connection N-M on BU7. The switch contacts are closed during operation and TS301 is then cut off. As soon as one of the contacts in the base circuit is opened, TS301 becomes conductive. Via diode GR301 the base of TS303 in the difference amplifier receives a negative voltage, so that the oscillator is blocked and the capacitors in the output circuit can discharge.

When the switching circuit is closed again, the oscillator is started after a short delay and the test voltage can assume the nominal value again. Switch contacts SK1 A1–3, SK1 B10 – 12, SK2/IV B and SK5/II serve to block the oscillator during switching-over. The smoothing capacitors are then discharged. When the circuit is switched on again, C301 provides a switch-on delay, so that the oscillator is not startet before C301 is charged. The charging time is determined by R303. To compensate for the delays caused by the transformer, the rectifier circuit and the smoothing capacitors in the control circuit (I-mode) and to prevent undesired oscillations, the oscillator voltage variations are transferred to the control circuit via capacitor C203 (Differential mode), thus providing stabilisation in the case of current control. Until C203 charged, there is a current through the base of TS310, so that this transistor is conductive and thus controls the difference amplifier. The oscillator output voltage is then gradually raised to the nominal value.

5. Current and voltage range selection

a. Current ranges

The measuring circuit for the current ranges is represented in Fig. 17. By means of step switch SK3 the desired current range is selected. R3 serves for fine adjustment of the limiting current within the preselected ranges.

From the generator the output voltage, in accordance with the preset range step, is applied to mode selector

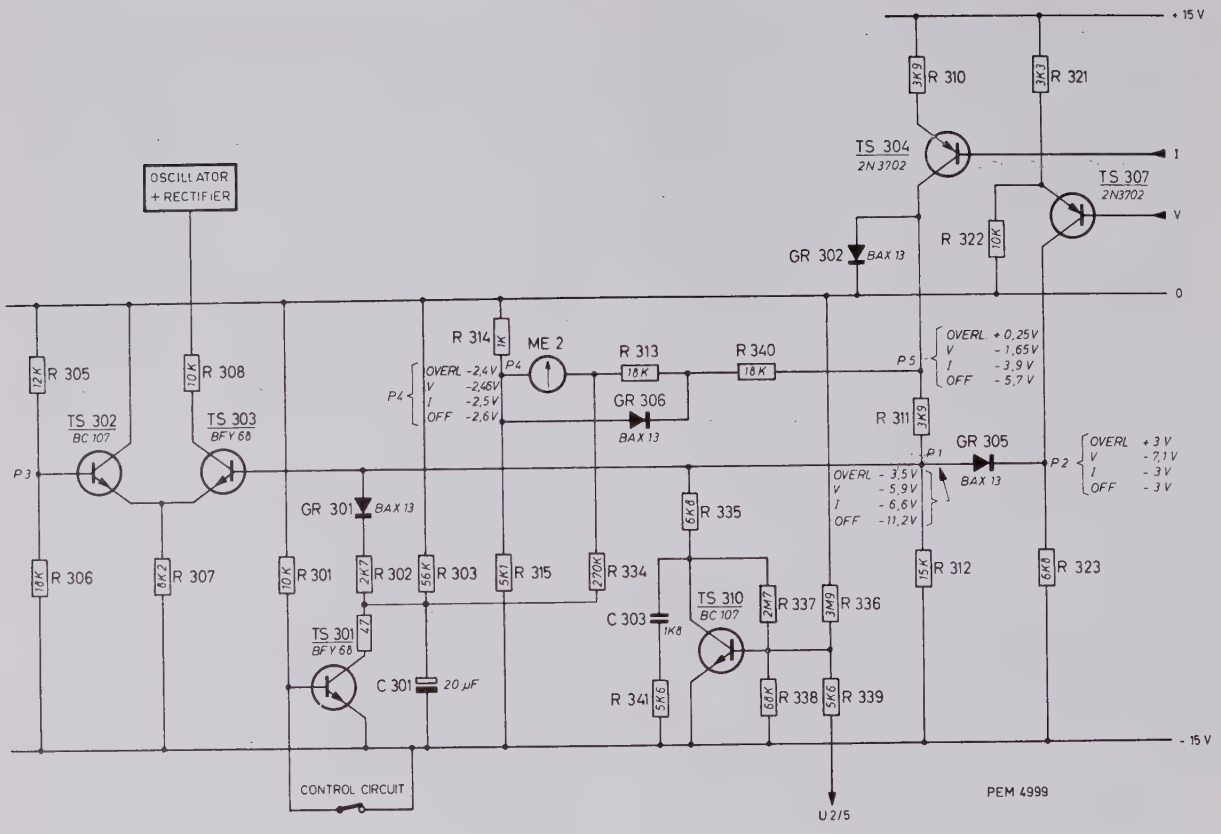


Fig. 16. Control switch and indicator control

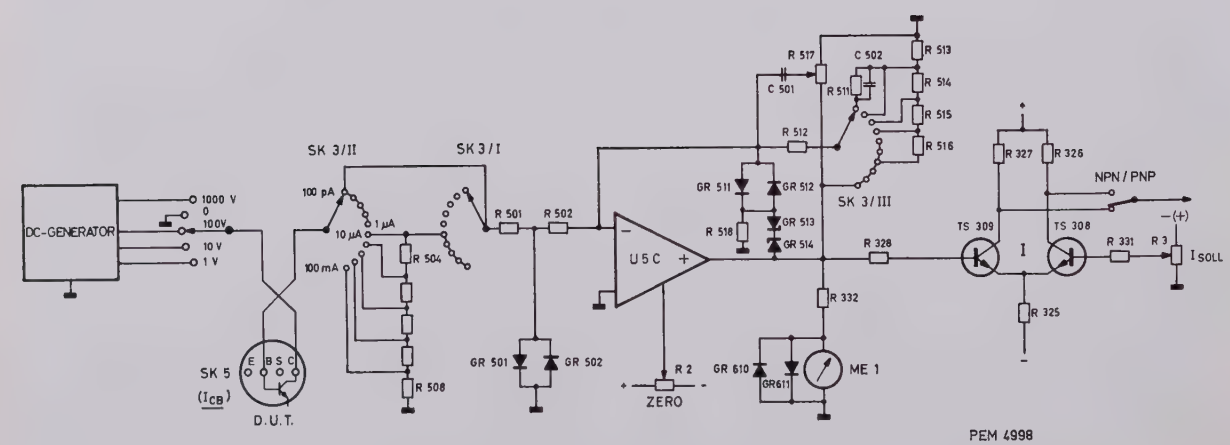


Fig. 17. Circuit of the current ranges

SK5 and consequently to the semi-conductor under test. From the latter the current flows to SK3/II, which together with SK3/I effects a division into two range groups. At the lower range steps up to 1 μA the current flows direct to the input of the measuring amplifier via R501 and R502. The higher current ranges are defined by resistors R504...R508, which form shunts for the measuring circuit. As a result the input signal across R504 will have almost the same value for all the higher range steps.

Measuring amplifier U 5 C is an operational amplifier stabilised by means of a chopper. In the absence of a drive signal it controls the output signal to 0 V (see description U5 C). As appears from Fig. 17, the lower range steps from 100 pA...1 μA are determined by a resistor divider in the feedback circuit. These resistors are connected to the circuit zero and change the degree of feedback in steps of a factor 10. The input current is directly current compensated by means of R512. The output of the measuring amplifier has the same voltage with respect to the circuit zero (when properly adjusted) as potentiometer R3. The voltage indicated by meter ME1 is proportional to the current applied.

Diodes GR501/GR502, GR511...GR514 and GR610/GR611 provide overload protection at the current ranges (e.g. short circuits at the 100 pA range!).

b. Voltage ranges

The generator has 3 different output voltages, the lowest of which serves for the 1 V and 10 V ranges and the other for the 100 V and the 1000 V ranges. By means of switch SK1 A/B the polarity can be reversed for PNP (–) or NPN (+) operation.

Fig. 18 shows the complete voltage dividing circuit. The circuit arrangement for the 1 V and 10 V ranges differ from that for 100 and 1000 V ranges. For the 1 V and 10 V ranges one side of the meter is connected to earth and resistors R401 and R403 are connected in series (Fig. 19). The output signal controls the difference amplifier which controls the output voltage of the oscillator until it has the reference value set with R1. The current measuring and control circuit is also shown in Fig. 19, in which the different circuit arrangement for the current ranges has been left out for simplicity (R504...R508); for this refer to Fig. 17. At the higher voltage ranges of 100 V and 1000 V the meter is connected in series with the control circuit (Fig. 20). It measures the current (I actual), which flows through control amplifier TS305/TS306 and which is determined by series resistors R405, R406...R408 and the test voltage. The resistors determine the measuring and control ranges, the current being proportional to the voltage on the semi-conductor under test.

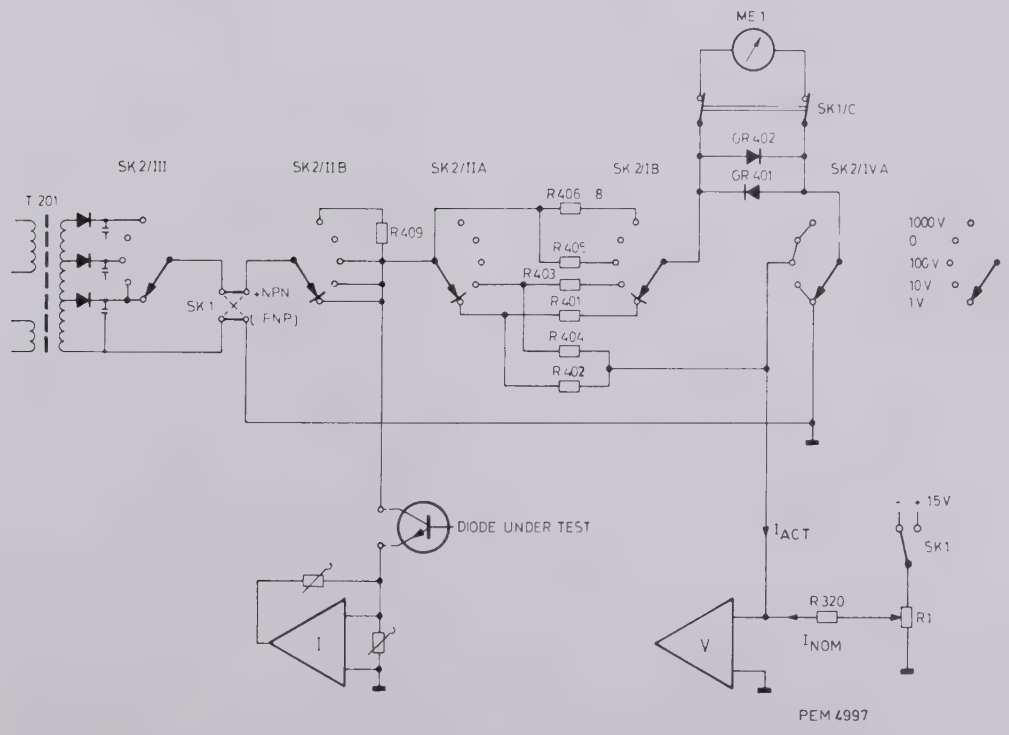


Fig. 18. Circuit of the voltage ranges

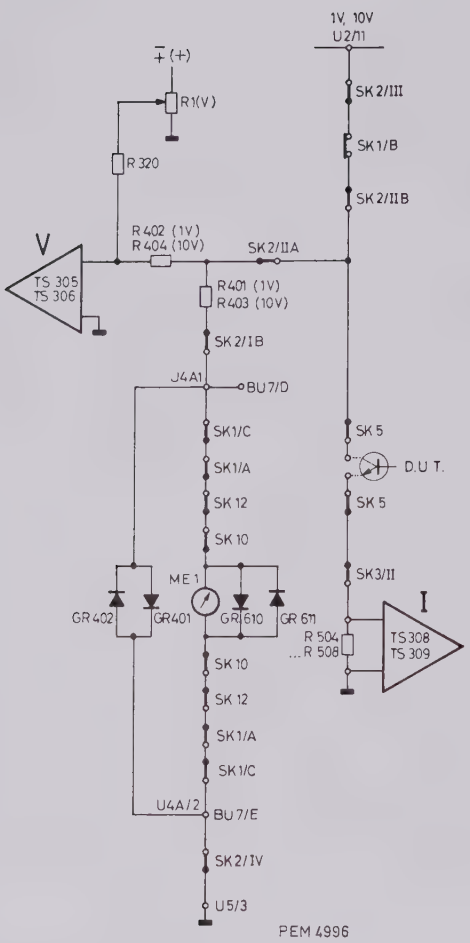


Fig. 19. Voltage measurement in the ranges 1 V and 10 V

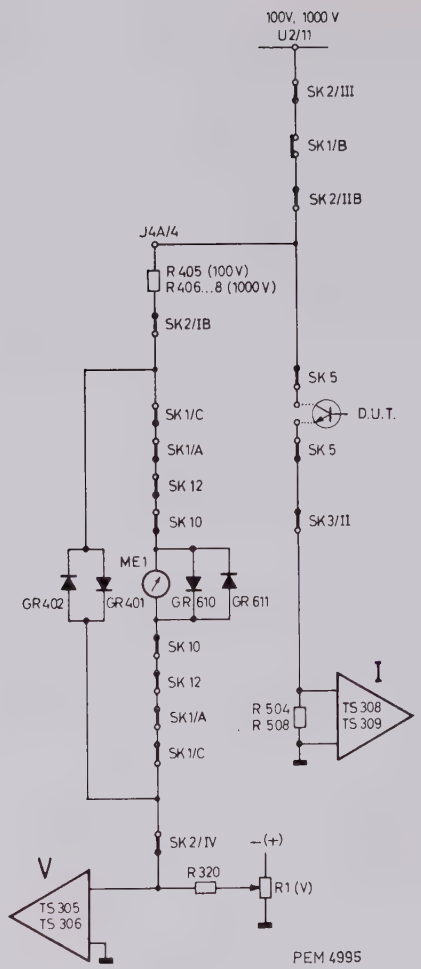


Fig. 20. Voltage measurement in the ranges 100 V and 1000 V

6. Mode of operation indicator

Moving-coil instrument ME2 indicates whether the test voltage source is current controlled or voltage controlled. The indicator can indicate 4 different conditions, viz. overload, V, A, Off (Fig. 21).

Fig. 21. Indicator scale

The deflection of the indicator depends on the setting of TS304 and TS307, which determines the voltage on points P1 and P2 (Fig. 16).

'OVERLOAD': In the case of overload TS304 and TS307 are bottomed, i.e. the nominal value is not obtained, so that the voltage on P5 is approx. + 0.25 V compared with – 2.4 V on P4. As a result the indicator will deflect to the extreme left.

'V': This indicator position is obtained when the generator is voltage controlled. TS307 is then cut off and the current from TS304 is drained via GR305 and R323. P2 is then more negative with respect to P1 (threshold voltage of the diode). TS304 is conductive and the voltage on point 5 will then be slightly more positive than that on P4 so that the indicator deflects in the 'V' range.

'A': In indicator position 'A' the generator is current controlled. TS304 conducts only slightly and TS307 is fully conductive. The voltage on P1 is then not influenced by TS307 (GR305 is cut off) and, on account of the collector-emitter current of TS304, a voltage of approx. – 4 V is present on P5 which is more negative than that on P4. The indicator pointer then deflects to the right in the 'A' range.

'OFF': The indicator position 'OFF' indicates that the control circuit is interrupted (also when the circuit is interrupted by the various switch contacts). In this situation transistors TS304 and TS307 are conductive. The voltage on P1 is negative, because TS301 is conductive and the control current is drained via GR301; the indicator then deflects to the right in the 'OFF' range.
To ensure an unambiguous indication in this position, resistor R334 has been included. In position 'OFF' TS301 is conductive and the collector potential will be practically −15 V. An additional current will then flow through ME2 and R314 to the circuit zero via R334.
Diode GR302 serves to limit the voltage on point P5 when, for instance, TS304 is fully conductive (in the case of OVERLOAD). The collector-emitter current then flows to zero via this diode and the voltage on P5 is limited to zero + the threshold voltage of GR302.
Diode GR306 has been included in parallel with indicator ME2 and resistor R313. This diode limits the deflection of ME2.

7. Measuring amplifier

To ensure accurate current measurements and current control at the most sensitive ranges, a highly sensitive measuring amplifier is required. This measuring amplifier or operational amplifier is a wide band amplifier stabilised by means of a MOS-FET transistor chopper. The block diagram of this amplifier is shown in Fig. 22.

Block diagram:

The input signal is first applied to a high and a low-pass filter. L.F. signals and direct voltages are converted into an alternating voltage by the Mos-Fet chopper. A.C. signals are applied direct to the difference amplifier and are suppressed for the chopper. The output signal of the chopper is amplified in a three stage amplifier and demodulated by a controlled rectifier.
The amplified d.c. output signal is then again applied to the difference amplifier which amplifies the input signal in its various stages. Both the demodulator and the chopper (modulator) are controlled by a synchronous signal, produced by an astable multivibrator.

Circuit diagram (Fig. 46):

For alternating voltages the amplifier input is connected direct to the input of the difference amplifier via C533. Direct voltages and alternating voltages with a low frequency ($\leqslant$ 10 Hz) are converted into an alternating voltage of approx. 120 Hz. by MOS-FET transistor TS534. Voltages with higher frequencies are short-circuited via C532, so that only direct voltages and LF voltage variations can reach TS534. The alternating voltage produced by the chopper can then be further amplified in a 3-stage a.c. amplifier. Via C541 the signal is applied to the gate of field-effect transistor TS538. This transistor forms an impedance matching stage and amplifies the signal which is then applied to the amplifier stages with TS539 and TS540. Zener diode GR537 provides a voltage threshold to adapt TS539 to the working point of TS538. Via R567 negative d.c. feed back is applied to the input of TS538; this ensures automatic control of the working point of the field-effect transistor. C542 serves for frequency correction at higher frequencies.
From the collector of TS540 the voltage signal is applied to the collector of TS541 via R572 and C544. The latter transistor operates as a controlled rectifier and demodulates the output signal in common mode with the chopper.
On the output of the rectifier a pulsating signal arises which is integrated by C543 and converted into a direct voltage. This direct voltage is applied to the opposite side of the difference amplifier, to the base of TS1.
Diodes GR538 and GR539 serve as a protection against excessively high voltages.

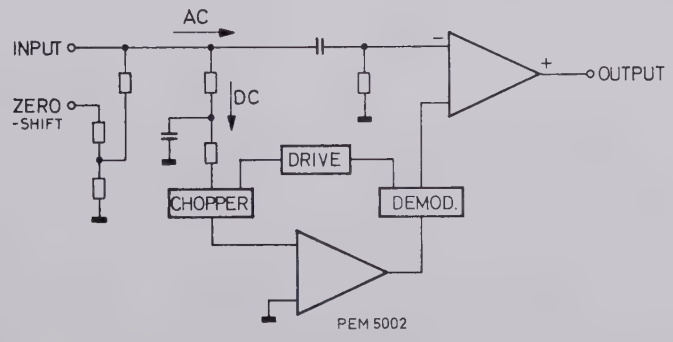


Fig. 22. Block diagram of the operational amplifier

Chopper drive:

The chopper drive circuit is supplied by a squarewave generator with a repetition frequency of approx. 120 Hz. An astable multivibrator (TS536 and TS537) operates as trigger source. To the output of this multivibrator an emitter follower stage (TS535) is connected. From the emitter of TS535 the chopper drive signal is applied to the gate of TS534. The chopper drive signal is a squarewave pulse going from 0 to −10 V. For demodulation the signal is taken from voltage divider R552...R555. This voltage divider is connected to a second divider, viz. R555, R556, and the collector emitter junction of TS536. This results in pulses of approx. +4.5 V and −0.5 V which turn TS541 on and off.

Owing to the 10-V control voltage, short needle pulses arise on the drain of MOS-FET transistor TS534, which pass the amplifier and are also amplified. To eliminate or attenuate these pulses, a voltage of opposite phase is applied via C531. Via this capacitor and potentiometer R551 the pulses reach the input, but in phase opposition. As a result the pulses on the input are compensated for. On account of the asymmetry of the compensation process only small pulses remain.

Integrated switching circuit TS542 with transistors TS1...TS8 is a two-stage difference amplifier with an emitter-follower output. The first difference amplifier consists of two pairs of transistors in Darlington arrangement so that they have a high current gain. To supply difference amplifier TS1...TS4, transistor TS8 has been included. This transistor functions as a constant current source in the emitter circuit. The output signal of the integrated circuit controls TS531. In the collector circuit of this transistor the push-pull output stage with TS532 + TS533 is incorporated. GR531 and GR532 supply a biasing voltage for the base-emitter diodes of TS532 and TS533. Diodes GR533 and GR534 serve to limit the current through the two output transistors. C535 and C536 are decoupling capacitors for the supply voltage.
To obtain a stable frequency response RC elements R535/C534 and R575/C545 are included. C546 also corrects the frequency response; due to its feedback it reduces the amplification of the high frequencies.
Balancing:
The input and output voltage are balanced with potentiometer R574 in difference amplifier TS3/TS4, which changes the base voltage of TS5. This adjustment should be effected for the current ranges 10 μA...100 mA. At the input of the measuring amplifier balancing in the case of current control is effected by means of a compensation voltage which is adjusted by means of potentiometer R2 (ZERO). Via R591 this voltage is applied to voltage divider R576/R577 and via R549 it is applied to the amplifier input; the zero adjustment is only operative in the smallest current ranges.

B. AUXILIARY VOLTAGE SOURCES

1. Electrode change-over:

The test voltage and the two auxiliary voltages are fed to the various electrode connections by means of rotary switch SK5. This switch has a special construction and its rotor is provided with connection sockets for the semi-conductors under test. This construction is necessitated by the sensitive measuring ranges where pico-amperes are measured on the one hand, and high test voltages may occur on the other. This switch must meet stringent requirements as regards insulation and parasitic capacitance. The direct connection of the electrodes to the wiper contacts reduces the circuit capacitance and simplifies the circuitry. The switch positions are separated by earthed intermediate positions to prevent interaction.

2. Stabilisation of the auxiliary voltage sources

The two auxiliary voltage sources for the third and fourth electrodes are identical. Therefore, only the source for the third electrode is described. The circuit diagram is shown in Fig. 23..
The amplifier with transistors TS601–TS604 has a differential input. One of the inputs is connected to voltage control R4. By means of this potentiometer the reference voltage for the amplifier is adjusted. Via resistor R607 the amplifier output voltage is fed back to the second input, the degree of feedback corresponding to switch position 1 V (SK 11). The amplifier controls the output voltage so that the difference between the two input signals, the reference voltage and the negative feedback voltage, becomes zero. At position 10 V (SK11) the degree of feedback is reduced by a factor 10 by R608. This resistor together with R607 forms a voltage divider. The output voltage is therefore 10 times higher. Moreover, series resistors R645 and R646 are switched in by means of switch SK11 for the two voltage ranges of the meter, and in position '0' the output is connected to the circuit zero.
Step switch SK7 with resistors R651...R657 is connected in series with the output circuits. By means of these resistors the current of the voltage source is limited so that it can be employed as a constant current source, and in position '0' the resistors can be employed as variable terminating resistors.
The difference amplifier with transistors TS601... TS604 is of the conventional type. Adjusting resistors R601 and R603 serve for adjusting the final value of the reference voltage range (10 V range).

In the case of overloading or short-circuiting of one or both of the auxiliary voltage sources, PTC resistor R643 functions as a protection resistor. When its temperature becomes higher its resistance also increases, so that the current is reduced. (To restore the normal condition the instrument should be switched off or the two sources should be switched off by means of SK11 and SK13).

C. POWER SUPPLY

1. Mains section (Fig. 43)

The PM 6509 has a power transformer (T1), which supplies the required operating voltages. On the primary side the mains transformer has two windings (S7 + S8), which can be connected in series or in parallel by means of switch SK14. In the case of series connection mains voltages of 230 V ± 15% are possible and in the case of parallel connection mains voltages of 115 V ± 15% are admissible. Thermal fuse VL1 protects the instrument against overloading in case of a short-circuit. Mains switch SK4 is included in the mains supply line. In the mains transformer a thermal fuse VL2 has been incorporated which interrupts the primary circuit, when its temperature rises to 125 °C. Windings S1 and S2 supply the voltages for the 3rd and 4th electrode (auxiliary voltages).
S5 and S6 supply the generator which delivers the voltage for the test current circuit.
The stabilised direct voltages of + 15 V and − 15 V are derived from windings S3 and S4.

2. Direct voltage sources + 15 and − 15 V

In principle the stabilised supply sources of + 15 and − 15 V are identical. For simplicity only the positive circuit is described. The negative circuit operates in a similar way, except for the polarities of the voltages and the transistors (Fig. 24).
The voltage from windings S3 and S4 of the mains transformer is applied to Graetz rectifier GR101. The output voltage of the latter is divided into a positive and a negative component, which are stabilised independent of each other.

Stabilisation of the + 15 V supply source:

The pulsating direct voltage is smoothed by electrolytic capacitor C101. The stabilising circuit consists of difference amplifier TS105/TS106, three regulators TS104, TS103 and TS102 and limiter TS101.
The reference voltage for the difference amplifier is provided by zener diode GR103, which ensures that the base voltage of TS106 is kept constant. The − 15 V output voltage is applied to the base of TS105 via voltage divider R106, R108 and R107. The voltage difference between the collectors of TS105 and TS106 controls TS104, which in turn controls the cascaded regulators TS103 and TS102.
When the divided output voltage deviates from the reference voltage, the voltage difference is compensated for by the control circuit.

Current limitation

The output current causes a voltage drop across resistor R101. When this voltage reaches a certain

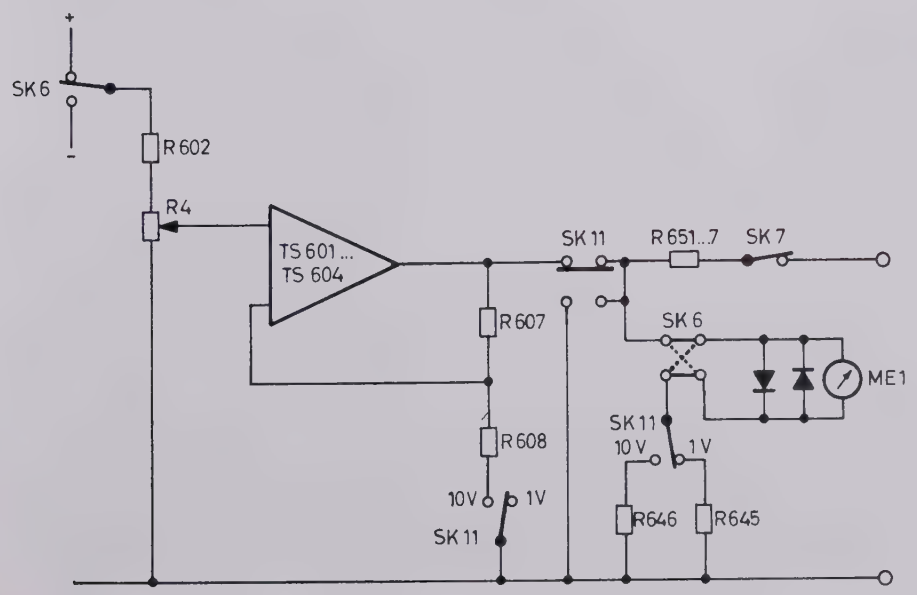


Fig. 23. Circuit principle of the auxiliary voltage sources

value, the current will flow to the base of TS101 via GR102 and R102, so that TS101 becomes conductive. Via the collector emitter junction of TS101 the control signal of TS104 flows direct to the positive potential and TS103 is driven to such an extent that the output current is kept constant at a certain value. At the moment that the current limiter becomes operative, the output voltage starts to decrease. As a result of this the direct voltage source is overload proof.

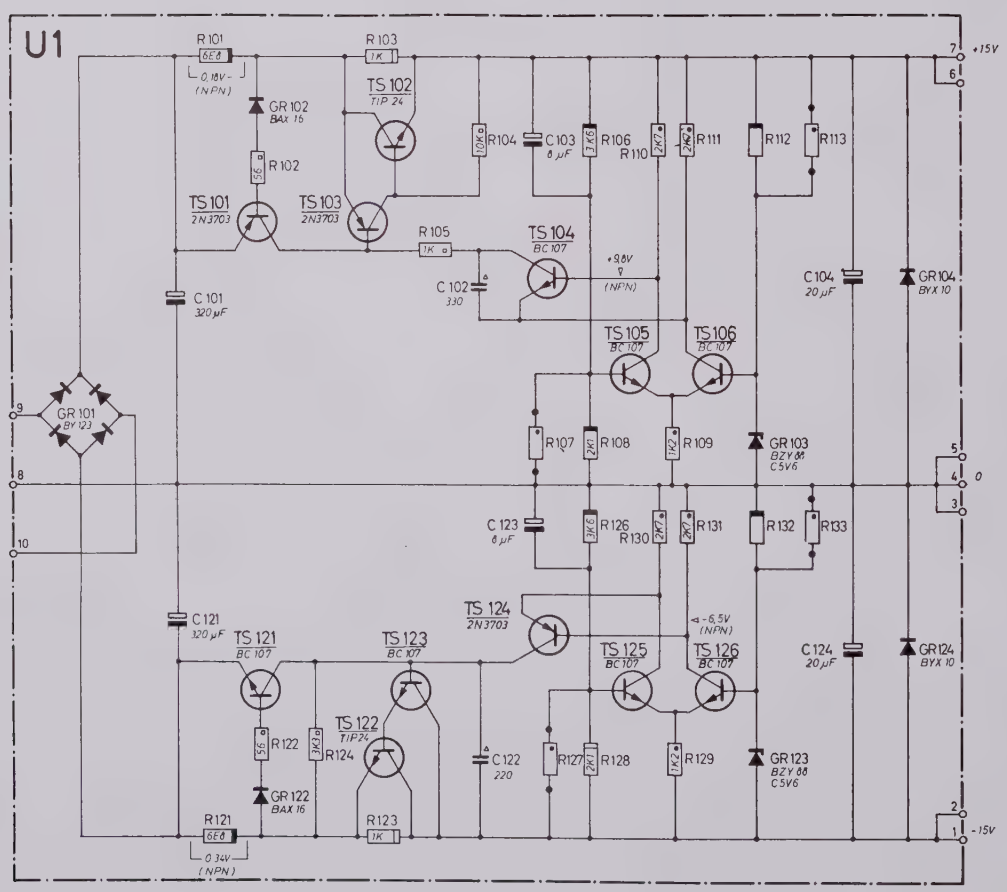


Fig. 24. Stabilised d.c. voltage sources +15 V and −15 V

VIII *Disassembling the instrument*

Caution

In this instrument high voltages of 100 V and 1000 V are generated. Therefore due care should be taken when working on a switched-on, opened instrument.

1. Cabinet

Top panel:

Turn screws 'A' a quarter turn and remove the panel in backward direction (Fig. 25).

Bottom panel:

Remove the tilting bracket, by compressing it slightly at one end. Remove the two screws at the rear of the instrument; the bottom panel can then be slid back and removed.

Side panels:

Remove the carrying bracket. The side panels can then be taken out.

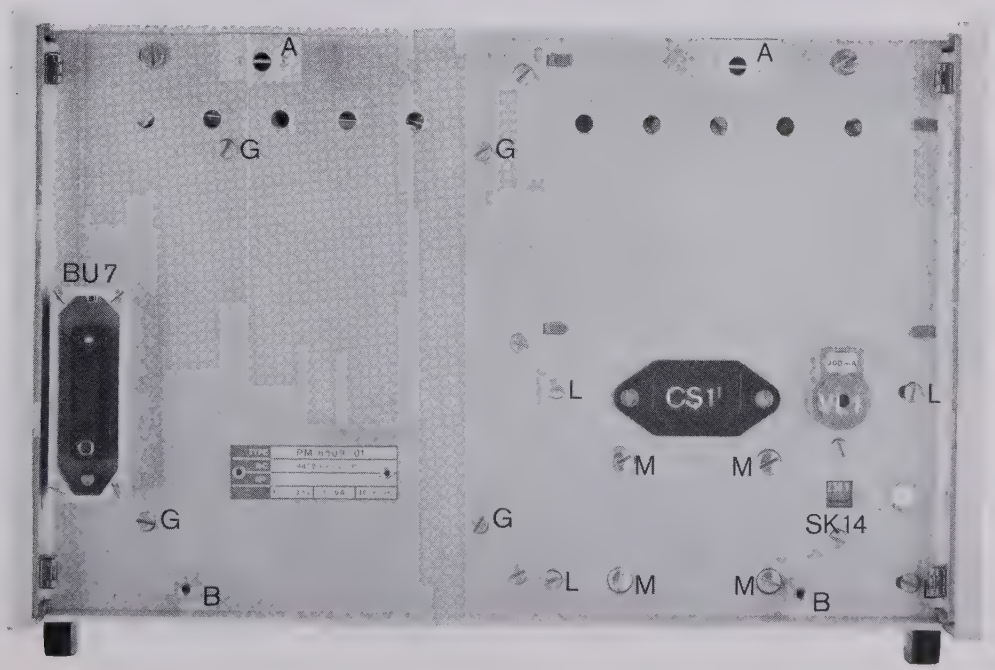


Fig. 25. Rear view

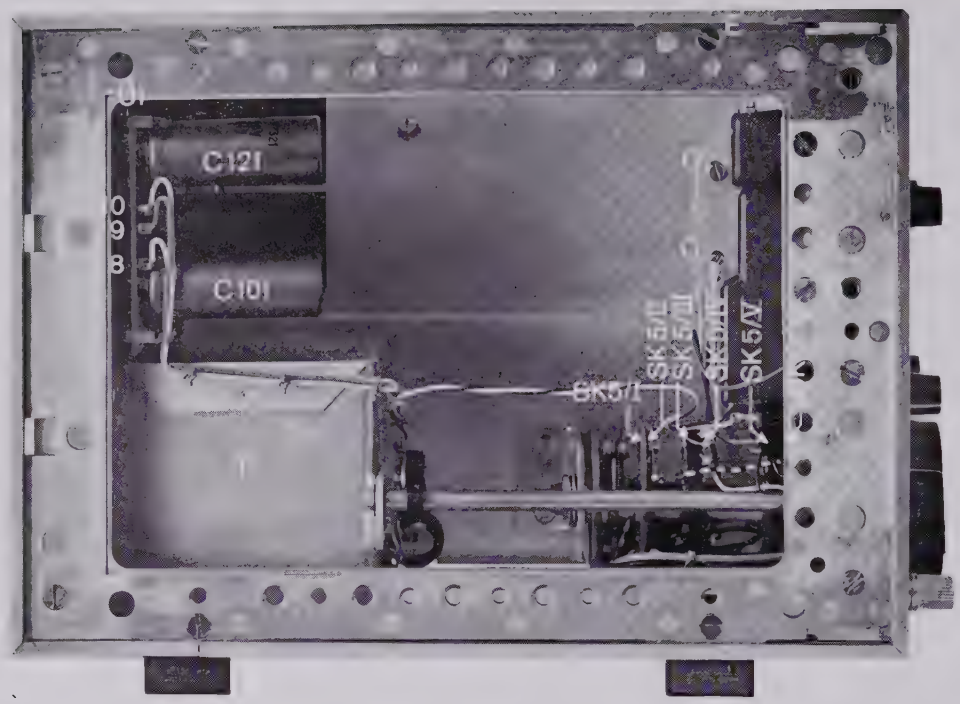


Fig. 26. Side view, left

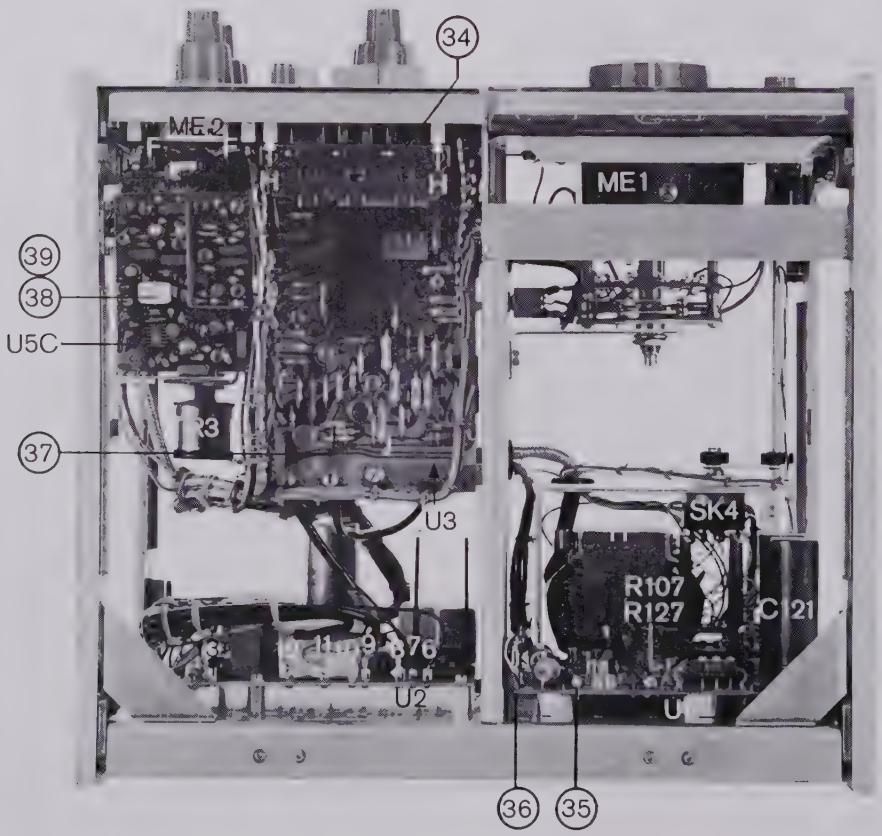


Fig. 27. Top view

2. Meter ME 1

- Remove the top and left-hand side panels.
- Unsolder the connection wires of the meter (caution: the meter housing is sensitive to heat).
- Remove screws 'C' and 'D' (Fig. 26).
- Slightly loosen screw 'E', and remove the meter together with the mounting plate in forward direction.

3. Indicator ME 2

- Remove the top panel.
- Unsolder the connection wires of the indicator.
- Remove the two screws 'F' and take out the instrument (Fig. 27).

4. Knobs (Fig. 28)

Dual knobs SK2, SK3, SK7 and SK9:

- Remove knob cap A and loosen screw B; the small knob can then be pulled off.
- Loosen nut C of the clamping cone by means of an 11-mm box spanner and pull off the knob. The diameter of the box spanner should not be more than 15.3 mm.

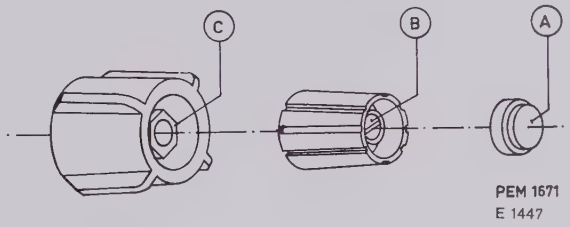


Fig. 28. Removing the knobs

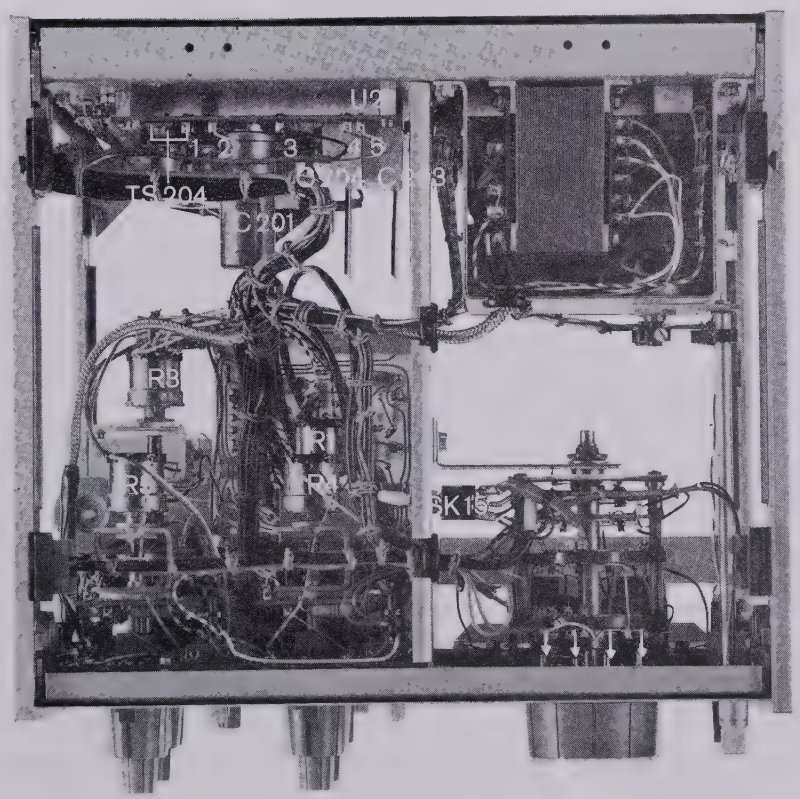


Fig. 29. Bottom view

Switch SK5

a. Remove the bottom panel.
b. Pull the connection wires one by one out of the sockets of the switch knob by means of tweezers (arrows in Fig. 29).
c. Remove the plate in the centre of the knob.
d. Loosen the clamping nut by means of a screwdriver and pull the knob forward.

Colours of the connection wires.

E = blue S = black ⏚ = green
B = yellow C = red

5. Units

Unit U1 (supply unit):

Remove the top and side panels. Printed circuit board U1 is fixed to the rear of the chassis by means of 4 clips and can be readily removed.

Unit U2 (oscillator):

Remove the upper, side and bottom panels. Printed circuit unit U2 is fitted on mounting pins at the rear of the chassis.
The unit can be removed after loosening the 4 screws 'G' at the rear of the instrument (Fig. 25).

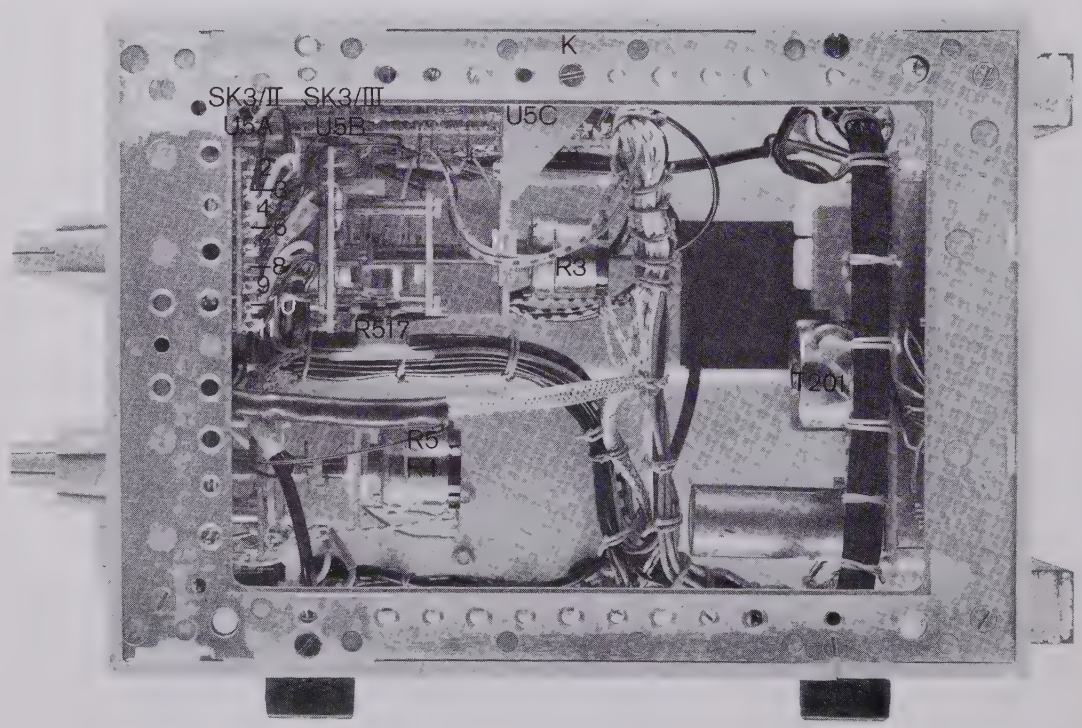


Fig. 30. Side view, right

Unit U3 (control unit):

Remove the top panel.

Remove two screws 'H' and screw 'J' (Fig. 27). After sliding the printed circuit board together with the push-button unit to the rear, the unit can be lifted out.

Unit 4 (Attenuator unit):

- Remove all the panels.
- Remove the two switch knobs of this unit.
- Remove the central fixing nuts; the unit can now be removed in backward direction (carefully unsolder the connection cable).

Unit U5 (switch unit):

- This unit is removed in the same way as U4, however, loosen screw 'K' (Fig. 30).

Unit U6 (electrode supply, Fig. 31):

- Remove the side panels and the bottom panel.
- Remove the knobs of SK7 and SK9 (Fig. 28).
- Remove the fixing nut of the switch. The unit can then be removed in downward direction.

Power transformer:

- Remove all the cabinet panels.
- Remove the two covers of the transformer housing.
- Remove the four fixing screwes 'L' at the rear of the instrument (Fig. 25).
- Pull the cable grommet out of the transformer casing and slide the casing back.
- Unsolder the connection wires from the transformer and from the soldering strip. Unsolder the screened cable from U6.
- Remove the 4 screws 'M' at the rear of the instrument and take out the transformer.

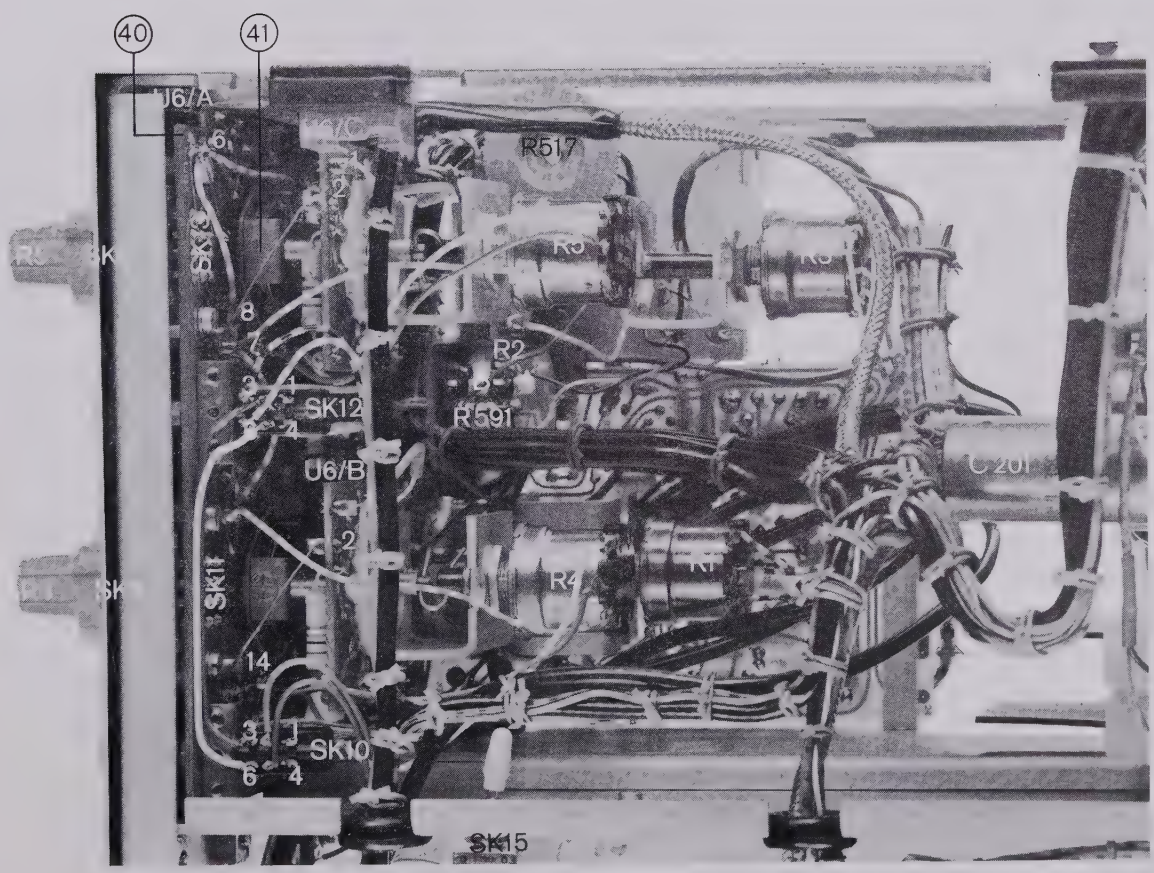


Fig. 31. Unit U6

IX *Maintenance*

The maintenance of this fully transistorised instrument may be restricted to the rotary switches and the push-button mechanism.
If required, the switch spindle bearings and the movable mechanical parts of the push-button switches may be lightly lubricated with thin fluid oil (sewing machine oil). For the ratchet it is advisable to use Molykote grease.
The switch contacts should only be treated with the special switch oil (for ordering number see list of mechanical parts).

To ensure the correct working of the instrument, it should be protected against the effects of moist, heat and dust.

Important: The high sensitivity of the measuring instrument requires a certain cable layout and a proper screening of certain leads. These screenings should never be interconnected, as otherwise earthing loops may arise. It is very important that the connections of the screenings are not altered, because this may give rise to errors which are hard to locate.

X *Survey of adjusting elements*

Checking and adjusting is effected in accordance with the instructions given in chapter XI 'Checking and adjusting'.

Adjusting element	*Fig.*	*Adjusting point*	*Required auxiliary equipment*	*Chapter XI point*
R113 R133	35	Adjustment of zener diodes GR103 and GR123	DC generator, mV meter	1a
R107 R127	35	Adjustment of the + 15 V and − 15 V	—	1b
R551	41	Amplifier U5C	Oscilloscope	3
R574	41	Amplifier U5C Zero-adjustment	Oscilloscope	3
R330	37	Current control	Digital voltmeter resistor, 5MΩ 0.2% ½ W resistor, 1MΩ 1% ½ W Precision resistance decade 50Ω...50GΩ	5
R601 R603 R621 R623	42	Auxiliary voltages for 3rd and 4th electrodes	Oscilloscope DC millivoltmeter	7

XI *Checking and adjusting*

The tolerances mentioned in the following description only apply to a completely readjusted instrument and may therefore deviate from the tolerances mentioned in chapter III. All adjusting elements, their functions and their location are indicated in chapter X.
For all checking and adjusting operations the following points should be observed:

- Before an adjustment is carried out, a general functional check should be performed; the instrument should contain no basic errors.
- All voltage or current sources of the instrument which are not required should be switched off.
- During adjustment the mains voltage should have the nominal value (115 V, or 230 V).
- During all measurements and adjustments with switched-on instrument, due care should be taken in order to avoid short circuits. Only use insulated screwdrivers and measuring clips!
- Before the measuring clips are connected and before soldering operations, always switch off the instrument!

1. + 15 V and − 15 V direct voltage source (U1)

Zener diodes GR103 and GR123 are used as reference sources for the stabilisation of these voltages. These zener diodes have been selected and adjusted as regards temperature coefficient.

a. Adjustment of the zener diodes

When zener diodes GR103 and GR123 are operated with a certain current, the temperature coefficient will become practically zero within a given temperature range. This current is adjusted as follows:

Resistor R113 (R133) should be selected so that the Zener voltage U_Z remains constant and $\triangle U$ does not deviate more than $\pm$ 1 mV when the zener diode is heated to approx. 60° C and then cooled down to a constant temperature of approx. 20° C. After this adjustment the zener current I_Z should lie between 3 A (R112//R113 $\leqslant$ 3 kΩ) and 6 mA (R112//R113 $\geqslant$ 1.5 kΩ) and voltage U_Z between 5.6 V and 5.8 V. If these voltages cannot be obtained, the zener diode is unsuitable.
The adjustment should be carried out outside the instrument in the measuring arrangement shown in Fig. 32. The diodes are heated up on the cathode connection by means of a non-earthed soldering iron whose temperature is kept at approx. 60° C by reducing its supply voltage.

b. + 15 and − 15 V output voltage

Adjustment of these voltages is effected with R107 for + 15 V and with R127 for − 15 V.
Permissible deviation of the output voltage 15 V $\pm$ 15 mV ($\pm$ 0.1%). The load current of the output voltage should be approx. 40 mA. For this purpose the connection wires on U1 points 6 + 7 (for + 15 V) and points 1 + 2 (for − 15 V) should be unsoldered. The outputs should then be loaded with a 390Ω, 5 W resistor each, to be connected to points 2 and 3 as well as 5 and 6 on U1.

c. Stability of the output voltages

At a load variation from 40 mA to 80 mA the voltage variation at the output should not exceed 3 mV. The

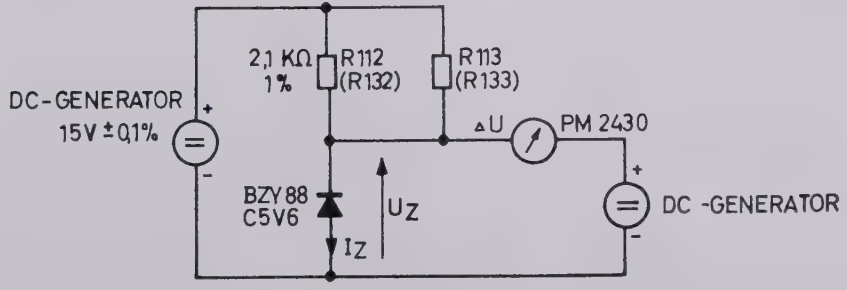


Fig. 32. Selecting the zener diodes

current limitation should become operative at max. 120 mA and the current should not exceed 165 mA at decreasing load resistance.
Checking is effected by means of an mA meter and a variable load resistor. The output voltage should be checked by means of the compensation method (according to Fig. 32, adjustment of zener diodes). At mains voltage variations of ± 15% with respect to the nominal value, the output voltage Ua should not vary more than ± 8 mV and the hum voltage should not be more than 150 μV (p-p) at a load of 80 mA; this should be checked by means of an oscilloscope.

2. Oscillator (U2)

a. Checking the output voltages

For checking the output voltages a voltmeter (e.g. digital voltmeter) should be connected to the test electrode (first letter in upper sector) i.e. to 'C' (BU6), 'E' (BU3) or 'B' (BU4) and ⏚ (BU1).
Set the voltage with SK2 and R1 and compare the meter deflection with that of the voltmeter. For this R1 should first be turned fully anti-clockwise and then gradually clockwise till the max. value is obtained.
Check the polarity: button NPN (+) depressed = + potential on the test electrode, − on ⏚ and vice versa in the case of PNP.

Control ranges	Permissible load current
0... 1.1 V	200 mA
0... 11 V	200 mA
0... 110 V	20 mA
0...1100 V	2 mA

b. Checking the current limitation

Connect a milli-ammeter (1...30 mA) to the test electrode and earth, as under point 1. The output voltage range is set with SK2 and the voltage with R1. When the mA meter is connected, the voltage drops and a short-circuit current arises which depends on the selected voltage range.

Voltage range	Limiting current
0... 1.1 V	approx 300 mA
0... 11 V	approx. 300 mA
0... 110 V	approx. 3.5 mA
0...1100 V	approx. 3.5 mA

3. Amplifier (U 5/C)

- Connect an oscilloscope to the collector of TS540 (casing) and ⏚.
- Set SK2 to O.
- Set SK3 to 1 μA.
- Adjust the spikes to minimum peak − peak value, with potentiometer R551 (< 1 Vp-p).
- Connect an oscilloscope to BU7 (socket at the rear of the instrument), sockets T and H/K (⏚).
- Set SK3 to 10 μA.
- Adjust the output voltage (DC) to zero (instr. I ⩽ 1%) with poteniometer R574. For this, R517 should be adjusted to the red mark. The amplifier should not oscillate.
- Set SK3 to 10, 1 and 0.1 nA.
- Adjust the output voltage to zero with potentiometer 'ZERO' (R2).
- When the 'METER' button is released, meter ME 1 should indicate zero.
- The voltage on U5/C with respect to ⏚ should not exceed ± 100 mV.

4. Voltage control (U3)

- Depress button NPN.
- Connect a digital voltmeter to socket 'C' (BU6) and ⏚.
- Set SK2 to 1 V.
- Set SK3 to 100 mA.
- Set SK5 to I_{CS} (fully anti-clockwise).
- Turn R3 fully clockwise.
- Depress the 'METER' button.
- R1: fully anti-clockwise, U = approx. + 0.05 V.
- Turn R1 slowly clockwise, U = approx. 1.1 V.
- Turn R1 back until the digital voltmeter indicates + 1000 V.
- Check the deflection of ME1: + 100 ± 1%.
- Connect a load resistor of 15Ω ± 5%, 1 W (wire-wound) to sockets C and S (BU6 and BU5).
- The output voltage should not vary more than ± 1%.
- Switch over to PNP; the digital voltmeter should indicate − 1000 V ± 5 mV, and ME1 should indicate 100 ± 1%.
- Check the voltages in the ranges 10 V, 100 V and 1000 V.

5. Current control (U3)

- Depress buttons 'NPN' and 'METER'.
- Set SK2 to 10 V.
- Turn R1 fully clockwise.
- Set SK3 to 1 μA.
- Turn R3 fully clockwise.
- Set SK5 to I_{CS} (fully anti-clockwise).
- Connect a 5 MΩ, 0.2% resistor to sockets C and S (BU5 and BU6).
- Connect a digital voltmeter to the amplifier, socket BU7, points T and H/K; deflection: ⩽ − 1.0 V.
- If the measuring value deviates, adjust R330 until the output voltage is − 1000 V ± 0.5%.
- Change the polarity with button PNP.
- The voltage on the amplifier output should now be 1,000 V ± 0.5%.
- The voltage between sockets 'C' (BU6) and ⏚

(BU1) should be 500 V ± 0.10 V (check with digital voltmeter).
- Turn R3 fully anti-clockwise.
- Release the meter button.
- Connect a 1 MΩ, 1%, 0.5 W resistor to BU5 and BU6.
- The voltage between 'C' (BU6) and ⏚ (BU1) should now be 50 mV, ± 15 mV. Check this by means of the digital voltmeter.
- Check all the current ranges.

SK3	100 mA	Load resistance 50 Ohm	± 1%
	10 mA	500 Ohm	
	1 mA	5 kOhm	
	100 µA	50 kOhm	
	10 µA	500 kOhm	
	1 µA	5 MOhm	
	100 nA	50 MOhm	± 2%
	10 nA	500 MOhm	
	1 nA	5 GOhm	± 5%
	100 pA	50 GOhm	

- When the meter button is released meter ME1 should indicate 100, ± 2% and when the button is depressed it should indicate 50, ± 2.5%. Mind the extra tolerance of the resistor.
- Check both polarities for each measurement.
- Turn potentiometer R517 at the right-hand side of the instrument so far clockwise that in the lower current ranges, in the case of current control (100 pA) the output voltage is as quiet as possible (adjust for a short integration time).
- Check the linearity of the scale at range 1 mA of SK3 (SK2: 100 V range). When, due to minus tolerances, adjustment to 100 is not possible because the current limiting starts, an auxiliary resistor of approx. 5.6 kOhm should be mounted in parallel to R330. This is only necessary for the linearity check so that no shift of the indicated zero-point occurs.

Deflection of ME1:		Resistor on BU5/BU6	
100 ± 0.2%	(to be	100 kOhm	± 0.2%
70 ± 1%	accurately	142.86 kOhm	
50 ± 1%	adjusted	200 kOhm	
30 ± 1%	with R1)	333.3 kOhm	
20 ± 1%		500 kOhm	
10 ± 1%		1 MOhm	
0		∞	

6. Indicator (U3)

- Set SK2 e.g. to the 100 V range and adjust R1 for a voltage of 100 V.
- Set SK3 to 1 mA and turn R3 fully clockwise.
- At zero load the indicator should show a distinct deflection in the 'V' range.
- Load the test circuit with a resistance decade (R = 110 kΩ) until the current is 95% of full-scale value; the indicator pointer should remain at 'V' and the voltage should become only < 1% less than the no-load voltage (nominal value).
- At a load of 100 kΩ ± 0.5% $\left(\frac{1\text{ mA}}{100\text{ V}}\right)$ the indicator should show f.s.d. both for voltage and current. The indicator pointer will then be at the transition.
- Decrease the load resistance until the voltage has decreased to 95%. The current should be 100% ± 1% and the indicator should deflect in the 'A' range.
- Set SK3 to 100 mA and turn R3 fully anti-clockwise.
- Load: 1 kΩ.
- The indicator should give a deflection in the 'A' range, and the deflection of ME1 should be approx. 5 mA with released 'METER' button.
- Turn R3 clockwise: the meter should now indicate max. 45 mA and the indicator should deflect in the 'OVERLOAD' range.
- Set SK5 to an arbitrary '0' position.
- Set SK2 to 0.
- Depress both or no push-buttons of SK1 A-B.
- The indicator pointer should now be in the 'OFF' range.

7. Electrode supply (U6)

- Check that the auxiliary voltages are applied to output sockets BU3...BU5 in accordance with the various switch positions of SK5. This should be checked by means of a voltmeter at every switch position of SK5.
- Check the polarity of the auxiliary voltage; the polarity indication (selectable with SK6 and SK8) refers to the third resp. fourth letter of the mode of operation selected with SK5, i.e. for I_{CS} B (electrode 3) and E (electrode 4). The common of the auxiliary voltages is connected to the reference electrode (for I_{CS} = S).
- Set SK5 to I_{CS}
- Set SK3 to 10 mA
- Connect a voltmeter and an oscilloscope to sockets B and S (BU4 and BU5, LOW to ⏚).
- Turn SK7 fully anti-clockwise, at 0.
- Set SK11 to 10.
- Set SK6 to +.
- R4: Turn it from left to right; the output voltage should be adjustable between 0...10 V, at positive and negative polarity (0 ⩽ 10 mV). If this is not the case, select other values for R601/R603 and R621/R623. The hum voltage component should not be more than 1% peak-peak, i.e. 100 mV at 10 V.
- Depress button SK10 and compare the meter deflec-

tion with that of the voltmeter. The polarity on BU4 should be positive (and negative when SK6 is changed over).
- Set SK11 to 0. The voltage should be 0 V ($\leqslant$ 50 mV).
- Set SK11 to 1 V. The output voltage should be adjustable between 0...1 V with R4.
- Set SK11 to 0.
- Set SK15 (accessible via aperture in the bottom of the instrument) to 'GROUNDED'.
- Connect an ohmmeter to BU4 and ⏚.
- Switch SK7 through all positions; the ohmmeter then indicates the resistance value given near the switch.
- Follow the same procedure for the second auxiliary voltage source, the ohmmeter should now be connected BU3 and BU5, with SK5 in position I_{CS}.

8. Electrode change-over NORMAL-GROUNDED

- Set SK5 to I_{CE}.
- Set SK1 to NPN (+).
- Depress METER button SK1 C.
- Set SK2 to 1 V.
- Set SK3 to 1 mA.
- Turn R1 and R3 fully clockwise.
- Connect a 330 ohm, 5%, 1.4 W resistor to sockets C and E (BU6 and BU3).
- Meter ME1 should indicate approx. 33 (330 mV corresponding to 330 Ω).
- Set SK6 and SK8 to –.
- Turn R4 and R5 fully clockwise.
- Set SK7 and SK9 to 1 kΩ.
- Set SK11 and SK13 to 1 V.
- Connect a ammeter between ⏚ (BU1) and 'B' or 'S' (BU4 and BU5).
- SK15 NORMAL: The indication of ME1 drops to approx. 0 V, if the mA meter is connected to B or S, or if these sockets are short-circuited (the current through the mA meter will be approx. –1 mA).
- SK15: GROUNDED: The voltage indication of ME1 remains the same, 33 (330 mV).
  The current indicated by the external instrument also remains the same (–1 mA).

9. Rise time

- SK5 to I_{CE}.
- Set SK1 to NPN.
- Set SK2 to 0.
- Set SK15 to NORMAL.
- Set SK3 to 100 pA.
- Turn R3 and R1 fully clockwise.
- Check that the METER button (SK1C) is released.
- Adjust the pointer to 0, +5/–0 pA with R2 and wait a few seconds.
- Set SK15 to position 'NORMAL'.
- Depress METER button SK1C.
- Set SK2 to 1000 V; the voltage should now slowly increase from 0 to + 1000 V. The rise time from 0 to 100% should be approx. 50 sec. The zero point then should not shift more than 15 scale divisions (approx. 1 minute after the charge).
  With low currents the great time constant should be watched; e.g. at 100 pF the voltage across the capacitor changes 1 V/s if the 100 pA-range is used.

XII *The shipment of the instrument*

In case of breakdowns one can always apply to the world-wide PHILIPS Service Organisation.
Whenever it is desired to send the instrument to a PHILIPS Service Centre for repair, the following points should be observed:
- Tie on a label bearing full name and address of the sender.
- Indicate as complete as possible the symptom(s) of the fault(s).
- Carefully pack the instrument in the original packing, or, if no longer available, in a wooden crate.
- Send the instruments to the adress provided by your local PHILIPS representative.

RESISTORS

Item	*Ordering code*	*Value*	*Watts*	*%*	*Description*
R1	4822 103 20084	1 Ω	3		Wire potmeter
R2	4822 102 10032	2x47 kΩ	3		Double potmeter
R3	4822 103 20087	100 Ω	3		Wire potmeter
R4	4822 103 20084	1 kΩ	3		Wire potmeter
R5	4822 103 20084	1 kΩ	3		Wire potmeter
R108	4822 116 50231	2.1 kΩ	0.4	1	Precision resistor
R112	4822 116 50231	2.1 kΩ	0.4	1	Precision resistor
R128	4822 116 50231	2.1 kΩ	0.4	1	Precision resistor
R132	4822 116 50231	2.1 kΩ	0.4	1	Precision resistor
R329	4822 113 10137	1.54 kΩ	0.4	0.5	Precision resistor
R332	4822 116 50472	1.87 kΩ	0.25	0.5	Metal film
R401	4822 116 50472	1.87 kΩ	0.25	1	Metal film
R402	4822 116 50204	2.87 kΩ	0.25	1	Metal film
R403	4822 116 50475	27.7 kΩ	0.25	1	Metal film
R404	4822 116 50476	28.7 kΩ	0.25	1	Metal film
R405	4822 116 50477	284 kΩ	0.25	1	Metal film
R406	4822 116 50397	953 kΩ	0.25	1	Metal film
R407	4822 116 50397	953 kΩ	0.25	1	Metal film
R408	4822 116 50397	953 kΩ	0.25	1	Metal film
R511	4822 111 40191	9 MΩ	1	1	Carbon
R512	4822 116 50022	1 MΩ	0.25	0.5	Metal film
R514	4822 113 20013	90 Ω	0.4	0.5	Precision resistor
R515	4822 113 40126	900 Ω	0.4	0.5	Precision resistor
R516	4822 116 50162	9 kΩ	0.25	0.5	Precision resistor
R517	4822 101 20001	47 kΩ	0.1	20	Potmeter
R551	4822 100 10024	10 kΩ	0.1	20	Potmeter
R574	4822 100 10024	10 kΩ	0.1	20	Potmeter
R643	4822 116 40002	50 Ω	0.5		P.T.C.-resistor
R645	4822 116 50472	1.87 kΩ	0.25	1	Metal film
R646	4822 116 50475	27.7 kΩ	0.25	1	Metal film

CAPACITORS

Item	*Ordering code*	*Value*	*Volts*	*%*	*Description*
C101	4822 124 40092	320 µF	40		Electrolytic
C103	4822 124 20091	8 µF	40		Electrolytic
C104	4822 124 20363	20 µF	25		Electrolytic
C121	4822 124 40092	320 µF	40		Electrolytic
C123	4822 124 20091	8 µF	40		Electrolytic
C124	4822 124 20363	20 µF	25		Electrolytic
C201	4822 124 40095	500 µF	40		Electrolytic
C202	4822 124 20073	32 µF	10		Electrolytic
C203	4822 124 40083	4.7 µF	100		Polyester
C204	4822 124 40083	4.7 µF	100		Polyester
C205	4822 124 10008	20 µF	15	20	Electrolytic
C206	4822 124 10074	150 µF	15	20	Electrolytic
C208	4822 124 40083	4.7 µF	100		Polyester
C209	4822 121 40035	0.15 µF	1,000	20	Plastic foil
C301	4822 124 20081	20 µF	16		Electrolytic
C302	4822 122 50024	100 pF	3,000 V	20	Ceramic
C501	4822 121 50234	6.8 nF	125	2	Polyester
C502	4822 121 40091	22 nF	250		Polyester
C540	4822 124 10091	33 µF	10	10	Electrolytic
C543	4822 124 10013	47 µF	10	6	Electrolytic
C601	4822 124 20182	250 µF	40		Electrolytic
C602	4822 124 20182	250 µF	40		Electrolytic
C604	4822 124 20085	1 µF	40		Electrolytic

LIMIT VALUES OF CHOICE ELEMENTS

When the instrument is adjusted, the values of the choice resistors should be selected within the following limits.
The choice elements can be recognised in the circuit diagram by the hatching over the elements and the lack of a value indication.

R107	18 kΩ...220 kΩ	R113	18 kΩ...220 kΩ
R127	18 kΩ...220 kΩ	R133	18 kΩ...220 kΩ
R330	15 kΩ... 1 MΩ	R601	47 Ω...680 Ω
R603	47 Ω...680 Ω	R621	47 Ω...680 Ω
R623	47 Ω...680 Ω		

TRANSISTORS

Item	*Ordering code*	*Type*
TS101	4822 130 40201	2N3703
TS102	4822 130 40341	TIP24
TS103	4822 130 40201	2N3703
TS104	4822 130 40184	BC107
TS105	4822 130 40184	BC107
TS106	4822 130 40184	BC107
TS201	4822 130 40201	2N3707
TS202	4822 130 40201	2N3703
TS203	4822 130 40341	TIP24
TS204	4822 130 40341	TIP24
TS301	4822 130 40414	BFY68
TS302	4822 130 40184	BC107
TS303	4822 130 40414	BFY68
TS304	4822 130 40207	2N3702
TS305-6	4822 130 40423	BCY87
TS307	4822 130 40207	2N3702
TS308-9	4822 130 40423	BCY87
TS310	4822 130 40184	BC107
TS531	4822 130 40354	BC177
TS532	4822 130 40184	BC107
TS533	4822 130 40354	BC177
TS534	4822 130 40346	MEM511A
TS535	4822 130 40184	BC107
TS536	4822 130 40184	BC107
TS537	4822 130 40184	BC107
TS538	4822 130 40408	BFW11
TS539	4822 130 40354	BC177
TS540	4822 130 40184	BC107
TS541	4822 130 40354	BC177
TS542	4822 209 80086	I.C.
TS601	4822 130 40239	BC109
TS602	4822 130 40239	BC109
TS603	4822 130 40207	2N3702
TS604	4822 130 40389	BFY67
TS621	4822 130 40239	BC109
TS622	4822 130 40239	BC109
TS623	4822 130 40207	2N3702
TS624	4822 130 40389	BFY67

DIODES

Item	*Ordering code*	*Type*
GR101	4822 130 30279	BY123
GR102	4822 130 30273	BAX16
GR103	4822 130 30193	BZY88/C5V6
GR104	4822 130 30195	BYX10
GR122	4822 130 30273	BAX16
GR123	4822 130 30193	BZY88/C5V6
GR124	4822 130 30195	BYX10
GR201	4822 130 30279	BY123
GR202	4822 130 30273	BAX16
GR203	4822 130 30296	BY140
GR204	4822 130 30256	BA148
GR205	4822 130 30256	BA148
GR206	4822 130 30256	BA148
GR301	4822 130 40182	BAX13
GR302	4822 130 40182	BAX13
GR303	4822 130 40182	BAX13
GR304	4822 130 40182	BAX13
GR305	4822 130 40182	BAX13
GR306	4822 130 40182	BAX13
GR401	4822 130 40182	BAX13
GR402	4822 130 40182	BAX13
GR501	4822 130 30303	BAY32
GR502	4822 130 30303	BAY32
GR511	4822 130 30303	BAY32
GR512	4822 130 30303	BAY32
GR513	4822 130 30193	BZY88/C5V6
GR514	4822 130 30193	BZY88/C5V6
GR531	4822 130 40182	BAX13
GR532	4822 130 40182	BAX13
GR533	4822 130 40182	BAX13
GR534	4822 130 40182	BAX13
GR535	4822 130 40182	BAX13
GR536	4822 130 40182	BAX13
GR537	4822 130 30286	BZY88/C6V2
GR538	4822 130 40182	BAX13
GR539	4822 130 40182	BAX13
GR601	4822 130 30279	BY123
GR602	4822 130 30286	BZY88/C6V2
GR603	4822 130 30286	BZY88/C6V2
GR610	4822 130 30273	BAX16
GR611	4822 130 30273	BAX16

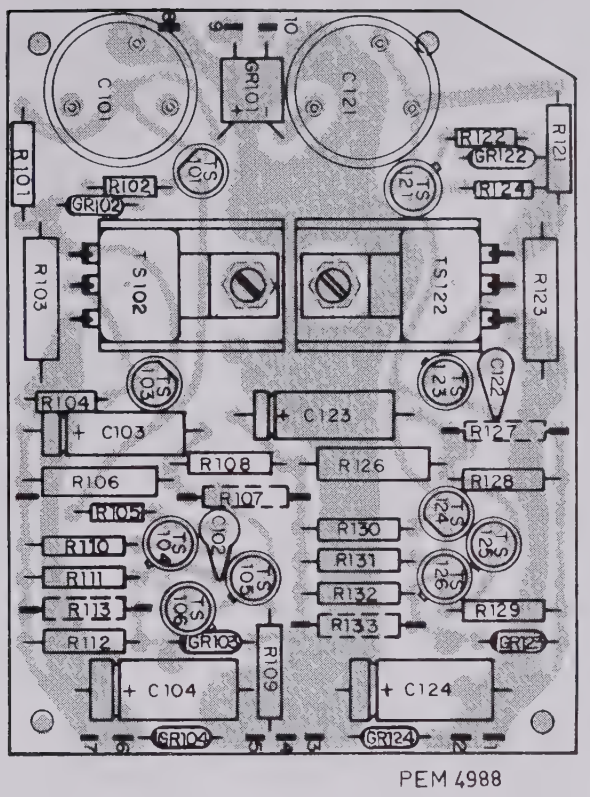


Fig. 35. D.C. Stabilising unit U1

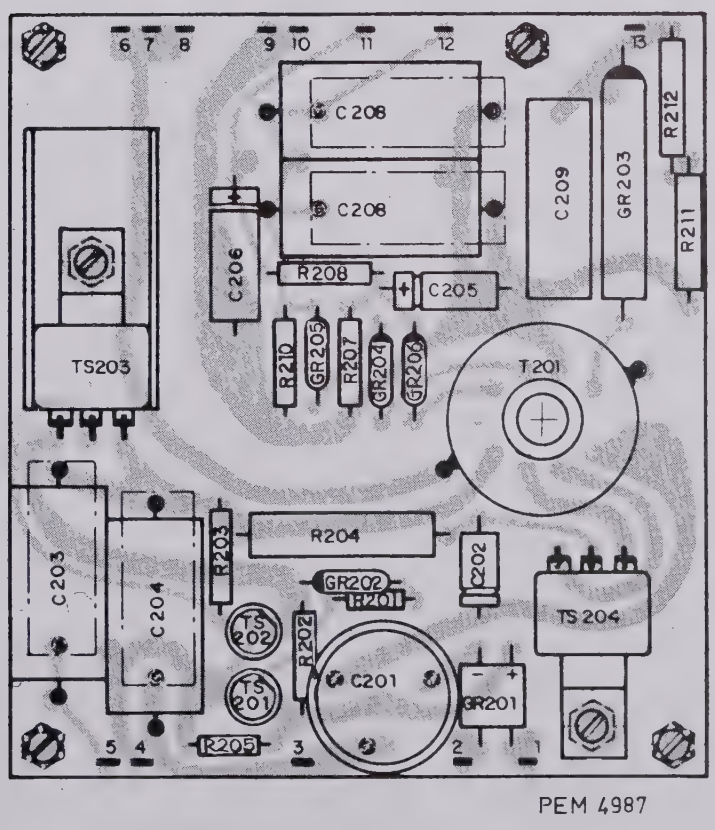


Fig. 36. D.C. Transformer unit U2

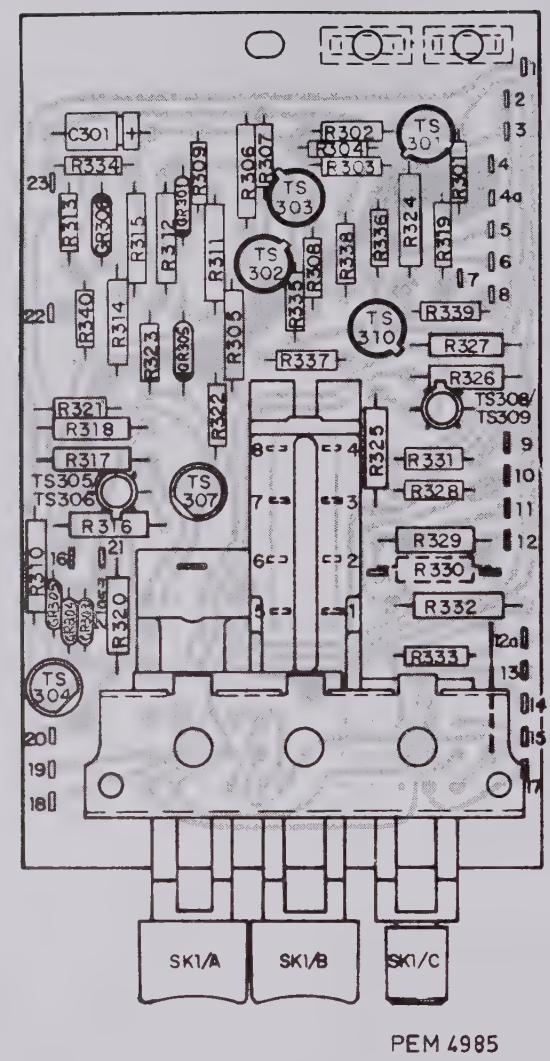


Fig. 37. Control unit U3

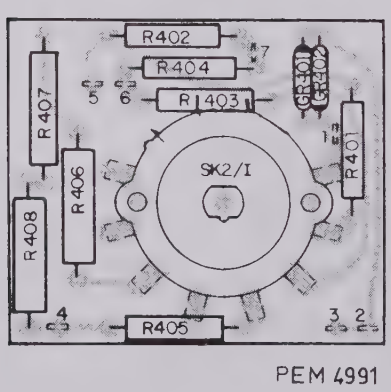


Fig. 38. Voltage ranges switch unit U4A

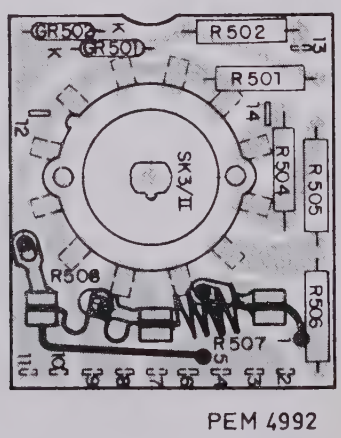


Fig. 39. Current ranges switch unit U5A

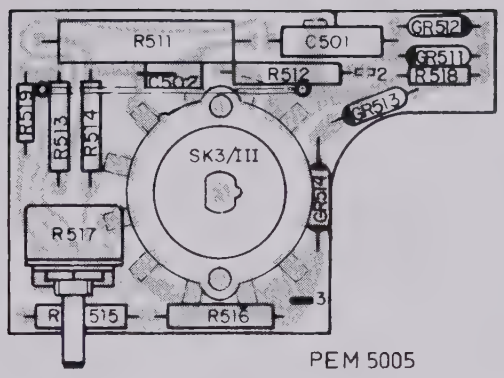


Fig. 40. Current ranges switch unit U5B

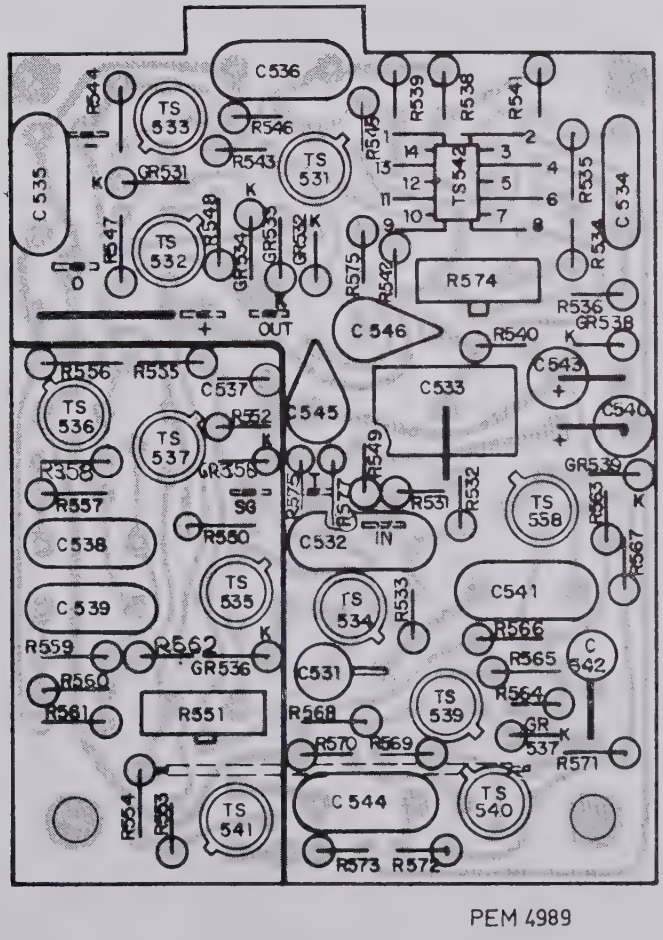


Fig. 41. Operational amplifier unit U5C

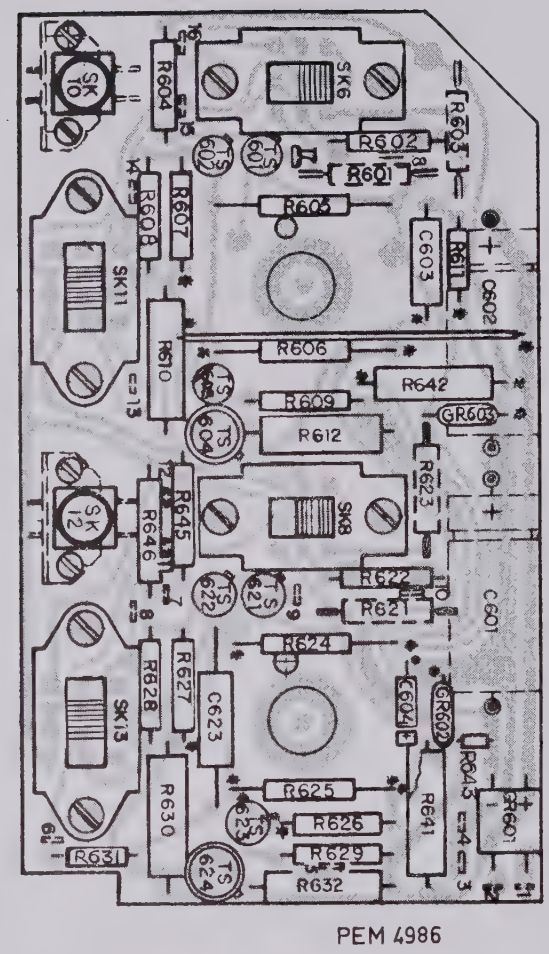


Fig. 42. Auxiliary voltage sources unit U6A

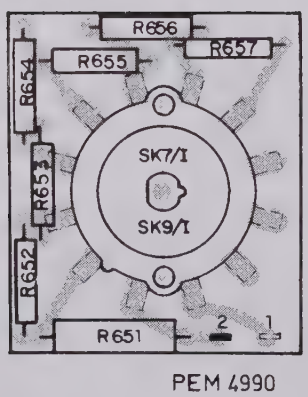


Fig. 43. Series resistors unit U6 B/C

R517 (right hand side)	Potentiometer for adjusting the integration time of the measuring amplifier.
BU1	Earth socket.
BU2	Transistor socket for transistor in TO5, TO18 or similar casings.
BU3= BU4= BU5= BU6=	emitter base screening (or 2nd gate) collector — socket for connection of semi-conductor under test or transistor adapter type PM 6544, PM 6547, PM 6548, PM 6549.
BU7	Sockets for external connections.
CS1	Mains input socket.
VL1	Safety fuse in primary mains circuit.
LA1	Pilot lamp for indication of the operating condition.
ME1	Meter with logarithmic scale.
ME2	Indicator showing whether current or voltage control takes place.

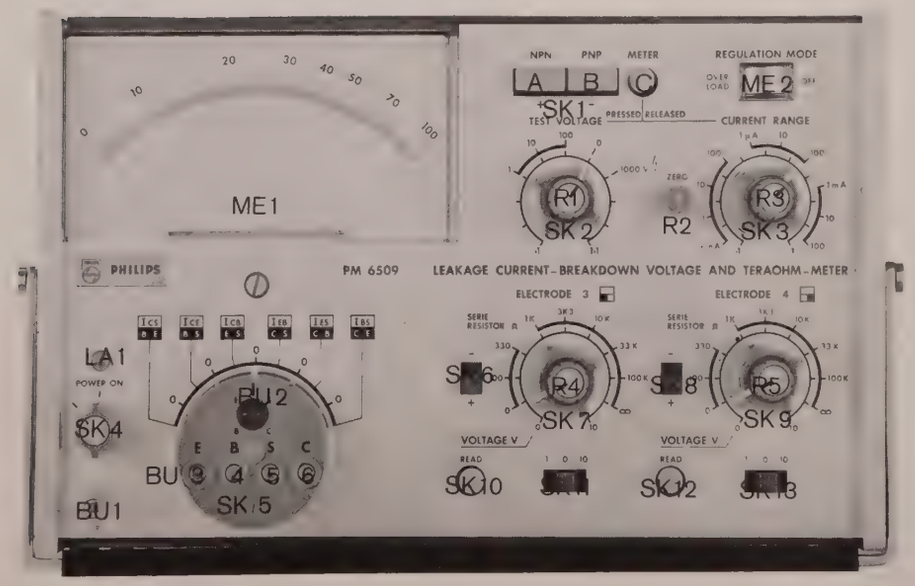


Fig. 2. Front view

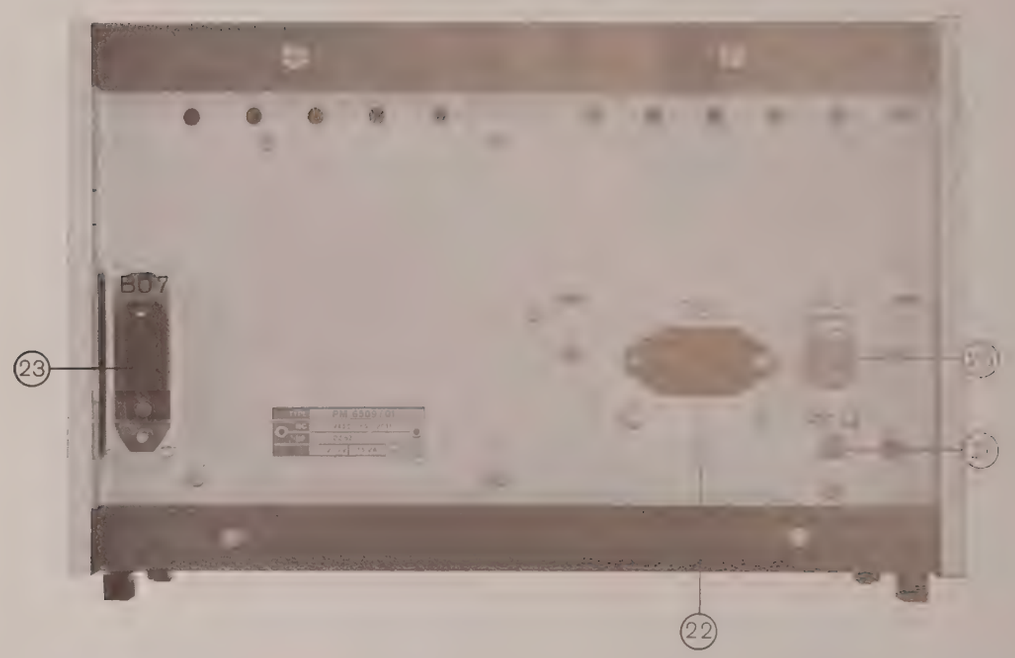


Fig. 3. Rear view

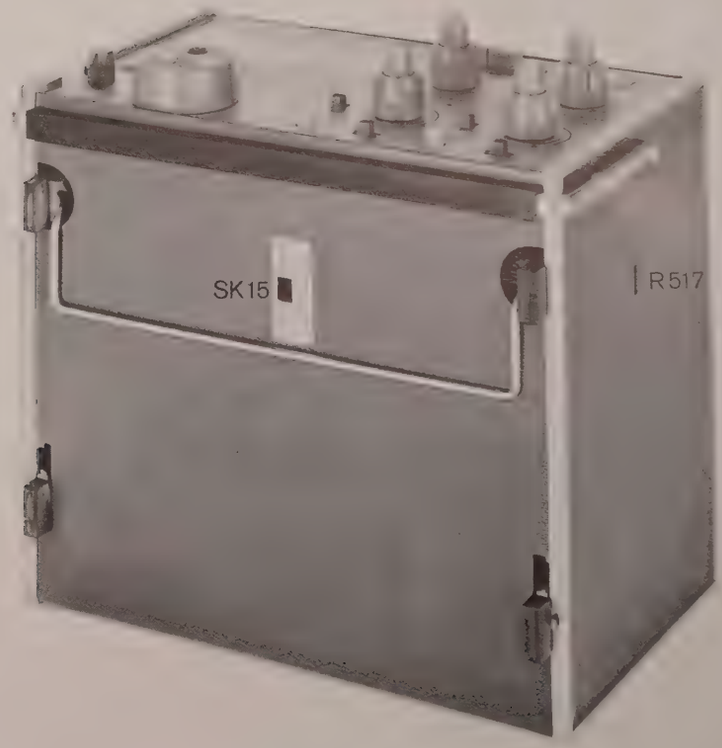


Fig. 4. Bottom view

Caution! The supply source for the test circuit can generate voltages up to 1100 V. Voltages which exceed 34 Vp may already be lethal. During operation, especially when turning the mode selector and connecting the semi-conductor under test, due care should always be taken; never touch the semi-conductor under test! At high voltages the mode selector should always be set to the zero position before touching the semi-conductor under test!

B. SWITCHING ON

The instrument is switched on by means of switch SK4, which should be set to position „ON". Pilot lamp LA1 indicates whether the instrument is switched on.

C. CONNECTION OF THE SEMI-CONDUCTOR UNDER TEST

For connecting the semi-conductor under test the knob of electrode switch SK5 has been provided with one transistor socket BU2 as well as four plug sockets BU3...6. Socket BU2 serves for connecting small types with wire terminals. For other types as well as for power transistors sockets BU3...6 are available.

The semi-conductor under test may be connected to these sockets via very short or screened leads. The sockets are also suitable for connection of transistor adapters (see optional accessories).

D. EXPLANATION OF THE WORKING WITH REFERENCE TO THE OPERATION

1. Selection of mode of operation and electrode arrangement

The main supply source is connected to those electrodes whose letter indications are in the upper section when switch SK5 (mode selector) is set to the relevant position (Fig. 5). The electrodes indicated by the two letters in the lower black or red sectors, are connected to the appertaining auxiliary or reference supply sources.

The reference point of the auxiliary voltages is always the second electrode, which normally represents the common potential of all the three supply sources. By means of switch SK5 all supply combinations can be selected which are possible with the 4 connections. The sequence of the modes has been selected so that the transistor junctions under test (I_{CE}, I_{CB} and I_{EB}) are adjacent, the central test junction I_{CB} usually permitting the highest voltage.

In the zero position between the individual contact positions all electrodes are disconnected. When switching over to an arbitrary zero position the energy supply to the voltage source is interrupted simultaneously, so that the output circuit can be discharged. This discharging process requires a certain time (exponential function, time constant approx. 0.3 sec. for 1000 V, 0.7 sec. for 100 V and 200 msec. for 10 V). When changing over to the mode with a lower test voltage, the switch should be left in the zero position for a short time (in accordance with the discharge time) before selecting the following mode.

It is, moreover, advisable – to exclude any risk when changing over to another mode – to set voltage range selector SK2 at its lowest range (1 V) and to turn voltage control R1 fully anti-clockwise. The two auxiliary voltage sources can be switched off by setting switches SK11, SK13 to 0.

Before changing over to a new position, the ratio between the electrode supply voltages should be determined again so that a corresponding setting can be chosen.

2. Polarity of the supply sources

The polarities of the supply sources can be adjusted arbitrarily. For the main test junction this is selected by means of buttons NPN or PNP. For transistors of the relevant type the appertaining diode junction is then connected in the reverse direction. The polarity indication + (for NPN) or – (for PNP) refers to the potential of the test electrode (first letter in upper indication sector). The two reference voltage sources each have a separate polarity switch (SK6 and SK8),

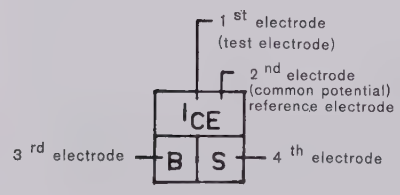
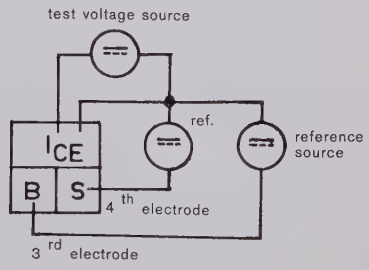


Fig. 5. Electrode arrangement



XIII *List of parts*

A. MECHANICAL

Fig.	*Qty.*	*Item*	*Ordering code*	*Description*
33	1	1	4822 466 60134	Ornamental strip
33	1	2	4822 347 10037	Indicator
33	1	3	4822 460 60018	Ornamental frame (right)
33	1	4	4822 413 30156	Adjusting knob
33	4	5	4822 413 40112	Switch knob
33	4	6	4822 413 70038	Cover
33	4	7	4822 413 30083	Adjusting knob
33	2	8	4822 276 10312	Push-button switch
33	2	9	4822 277 20074	Sliding switch (3-pos)
33	2	10	4822 277 20075	Sliding switch (2-pos)
33	1	11	4822 413 50675	Knob, complete
33	1	12	4822 255 40002	Transistor support
33	1	13	4822 290 40012	Earthing terminal
33	1	14	4822 413 70038	Cover
33	1	15	4822 413 30329	Switch knob
33	1	16	4822 381 10116	Lens
33	1	17	4822 455 90335	Instruction plate
33	1	18	4822 347 40013	Meter
33	1	19	4822 460 60014	Ornamental frame (left)
3	1	20	4822 256 40026	Fuse holder
3	1	21	4822 277 20014	Sliding switch (2-pos)
3	1	22	4822 265 30066	Mains socket
3	1	23	4822 276 50079	Terminal strip
34	1	24	4822 216 70108	D.C. Convertor U2
34	1	25	4822 146 30251	Mains transformer
33	1	26	4822 273 40219	Mains switch
33	1	27	4822 273 80125	Rotary switch
33	1	28	4822 255 10007	Lamp support
33	1	29	4822 277 10169	Tumbler switch
33	2	30	4822 462 40092	Foot, complete
33	1	31	4822 413 50487	Adjusting knob
33	2	32	4822 462 50101	Foot, complete
33	4	33	4822 462 40157	Foot rubbers
27	1	34	4822 276 30152	Push-button switch
27	1	35	4822 216 70106	Power supply print U1
27	4	36	4822 693 40002	Print support
27	1	37	4822 216 70107	Control print U3
27	1	38	4822 273 10055	Switch unit U5
27	1	39	4822 216 70109	Amplifier unit U5C
31	1	40	4822 216 70111	Voltage sources unit U6A
31	2	41	4822 273 10054	Switch SK7, SK9
34	2	42	4822 273 10053	Switch unit U4
	1	43	4822 321 10071	Mains cable IEC
	1	44	4822 390 10007	Switch oil
	1	LA1	4822 134 40005	Lamp (7999 D/00)
	1	VL1	4822 253 30012	200 mA-fuse (delayed action)

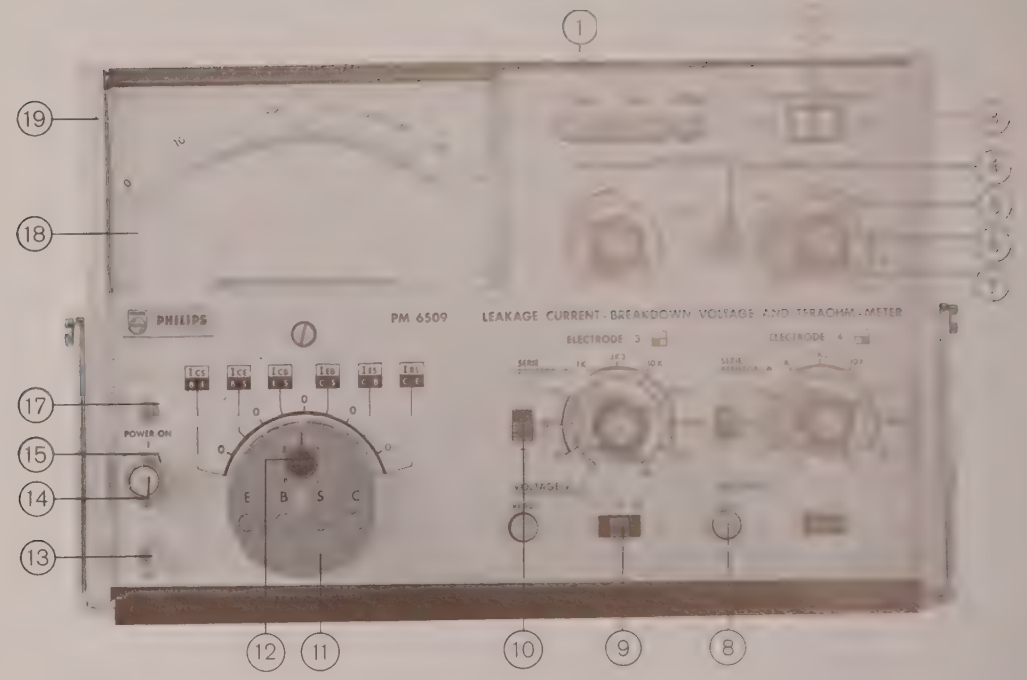


Fig. 33. Front view with item numbers

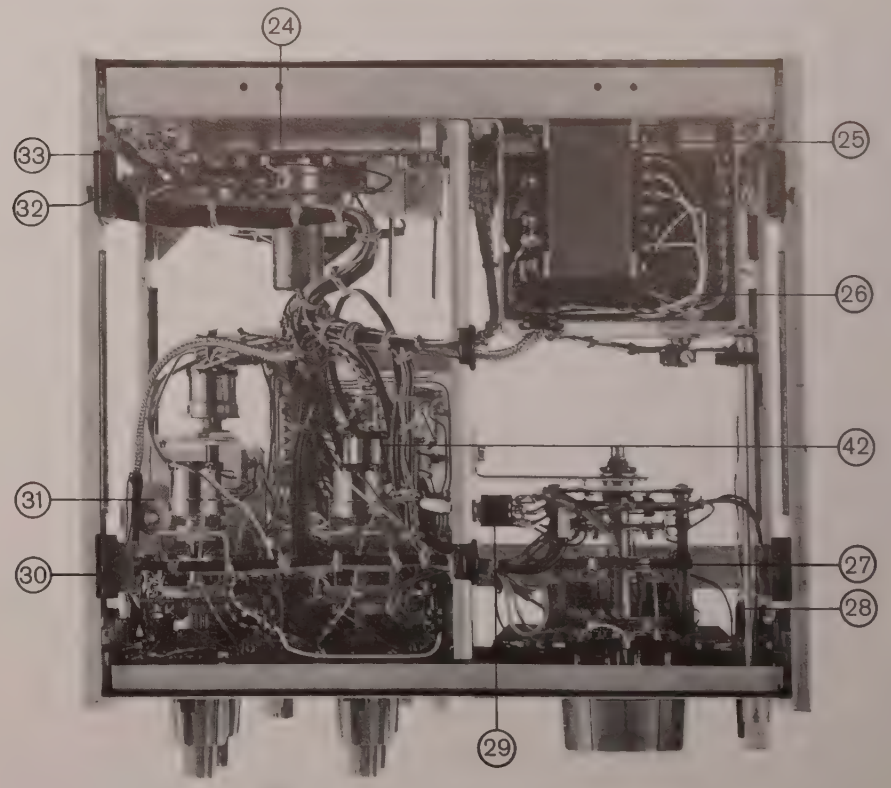


Fig. 34. Bottom view with item numbers

B. ELECTRICAL — ELEKTRISCH — ELEKTRISCH — ELECTRIQUE — ELECTRICOS

This parts list does not contain multi-purpose and standard parts. These components are indicated in the circuit diagram by means of identification marks. The specification can be derived from the survey below.

Diese Ersatzteilliste enthält keine Universal- und Standard-Teile. Diese sind im jeweiligen Prinzipschaltbild mit Kennzeichnungen versehen. Die Spezifikation kann aus nachstehender Übersicht abgeleitet werden.

In deze stuklijst zijn geen universele en standaardonderdelen opgenomen. Deze componenten zijn in het principeschema met een merkteken aangegeven. De specificatie van deze merktekens is hieronder vermeld.

La présente liste ne contient pas des pièces universelles et standard. Celles-ci ont été repérées dans le schéma de principe. Leurs specifications sont indiquées ci-dessous.

Esta lista de componentes no comprende componentes universales ni standard. Estos componentes están provistos en el esquema de principio de una marca. El significado de estas marcas se indica a continuación.

Carbon resistor E24 series
Kohleschichtwiderstand, Reihe E24
Koolweerstand E24 reeks
Résistance au carbone, série E24
Resistencia de carbón, serie E24
— 0,125 W 5%

Carbon resistor E12 series
Kohleschichtwiderstand, Reihe E12
Koolweerstand E12 reeks
Résistance au carbone, série E12
Resistencia de carbón, serie E12
— 0,25 W ≦ 1 MΩ, 5%
— > 1 MΩ, 10%

Carbon resistor E24 series
Kohleschichtwiderstand, Reihe E24
Koolweerstand E24 reeks
Résistance au carbone, série E24
Resistencia de carbón, serie E24
— 0,5 W ≦ 5 MΩ, 1%
— > 5 ≦ 10 MΩ, 2%
— > 10 MΩ, 5%

Carbon resistor E12 series
Kohleschichtwiderstand, Reihe E12
Koolweerstand E12 reeks
Résistance au carbone, série E12
Resistencia de carbón, serie E12
— 0,5 W ≦ 1,5MΩ, 5%
— > 1,5MΩ, 10%

Carbon resistor E12 series
Kohleschichtwiderstand, Reihe E12
Koolweerstand E12 reeks
Résistance au carbone, série E12
Resistencia de carbón, serie E12
— 1 W ≦ 2,2 MΩ, 5%
— > 2,2 MΩ, 10%

Carbon resistor E12 series
Kohleschichtwiderstand, Reihe E12
Koolweerstand E12 reeks
Résistance au carbone, série E12
Resistencia de carbón, serie E12
— 2 W 5%

Wire-wound resistor
Drahtwiderstand
Draadgewonden weerstand
Résistance bobinée
Resistencia bobinada
— 0,4 – 1,8 W 0,5%

Wire-wound resistor
Drahtwiderstand
Draadgewonden weerstand
Résistance bobinée
Resistencia bobinada
— 5,5 W ≦ 200 Ω, 10%
— > 200 Ω, 5%

Wire-wound resistor
Drahtwiderstand
Draadgewonden weerstand
Résistance bobinée
Resistencia bobinada
— 10 W 5%

Tubular ceramic capacitor
Rohrkondensator
Keramische kondensator, buistype
Condensateur céramique tubulaire
Condensador cerámico tubular
— 500 V

Tubular ceramic capacitor
Rohrkondensator
Keramische kondensator, buistype
Condensateur céramique tubulaire
Condensador cerámico tubular
— 700 V

Ceramic capacitor, "pin-up"
Keramikkondensator "Pin-up" (Perltyp)
Keramische kondensator "Pin-up" type
Condensateur céramique, type perle
Condensador cerámico, versión "colgable"
— 500 V

"Microplate" ceramic capacitor
Miniatur-Scheibenkondensator
"Microplate" keramische kondensator
Condensateur céramique "microplate"
Condensador cerámico "microplaca"
— 30 V

Mica capacitor
Glimmerkondensator
Micakondensator
Condensateur au mica
Condensador de mica
— 500 V

Polyester capacitor
Polyesterkondensator
Polyesterkondensator
Condensateur au polyester
Condensador polyester
— 400 V

Flat-foil polyester capacitor
Miniatur-Polyesterkondensator (flach)
Platte miniatuur polyesterkondensator
Condensateur au polyester, type plat
Condensador polyester, tipo de placas planas
— 250 V

Paper capacitor
Papierkondensator
Papierkondensator
Condensateur au papier
Condensador de papel
— 1000 V

Wire-wound trimmer
Drahttrimmer
Draadgewonden trimmer
Trimmer à fil
Trimmer bobinado

Tubular ceramic trimmer
Rohrtrimmer
Buisvormige keramische trimmer
Trimmer céramique tubulaire
Trimmer cerámico tubular

For multi-purpose and standard parts, please see PHILIPS' Service Catalogue.

Für die Universal- und Standard-Teile siehe den PHILIPS Service-Katalog.

Voor universele en standaardonderdelen raadplege men de PHILIPS Service Catalogus.

Pour les pièces universelles et standard veuillez consulter le Catalogue Service PHILIPS.

Para piezas universales y standard consulte el Catálogo de Servicio PHILIPS.

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India: Philips India Ltd., PIT/S.E. Dept., Dugal House, 169 Backbay Reclamation, Bombay 1; tel. 245144

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Ireland: Philips Electrical (Ireland) Ltd., Newstead, Clonskeagh, Dublin 14; tel. 976611

Island: Mr. Snorri P.B. Arnar, P.O.B. 354, Reykjavik; tel. 13869

Islands Canarias: Philips Ibérica S.A.E., Triana 132, Las Palmas 39-41 Santa Cruz de Tenerife

Israël: Israelectra Ltd., 12, Allenby Road, P.O.B. 1608, Haifa; tel. 526231

Italia: Philips S.p.A., Casella Postale 3992, Milano; tel. 69.94

Liban: Philips Liban S.A., P.O.B. 670, Beyrouth; tel. 232303-232458/59

Malaya: Philips Singapore Ltd., P.O.B. 1358 N.T.S. Building, d'Almeida Street, Singapore; tel. 94914

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Perú: Philips Peruana S.A., Apartado Postal 1841, Lima; tel. 34620-40265

Philippines: Electronic Development & Application Center, Room 715, Don Santiago Bld., 1344 Taft Avenue, Manila

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Rwanda: Philips Rwanda S.A.R.L., B.P. 449, Kigali

Schweiz-Suisse-Svizzera: Philips A.G., Binzstrasse 18, Zürich; tel. 051 44 22 11

Singapore: Philips Singapore Ltd., P.O.B., 1358, N.T.S. Building, d'Almeida Street, Singapore 1

South Africa: South African Philips (Pty) Ltd., P.O.B. 7703, 2, Herb Street, New Doornfontein, Johannesburg; tel. 24-0531

Suomi: Oy Philips Ab, Frederikinkatu 48, Helsinki; tel. 10915

Sudan: Gellatly Hankey & Co. (Engineering) Ltd., P.O.B. 150, Khartoum; tel. 71183

Sverige: Svenska A.B. Philips, Fack, Lidingövägen 50, Stockholm 27; tél. 08/635000

Syrie: Philips Moyen Orient S.A., P.O.B. 2442, Damas; tel. 18605-21650

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Türkiye: Türk Philips Ticaret A.S., Posta Kutusu 504, Istanbul; tel. 447486

Uruguay: Philips de Uruguay, Avda Uruguay 1287, Montevideo; tel. 956 41-2-3-4

U.S.A.: Philips Electronic Instruments, 750 South Fulton Ave., Mount Vernon, N.Y. 10550-(914) 664-4500

Venezuela: C.A. Philips Venezolana, Apartado Postal 1167, Caracas; tel. 72 01 51

Zambia: Philips Electrical Ltd., Freetown Road, P.O.B. 553, Kitwe; Philips Electrical Ltd., P.O.B. 1878, Lusaka

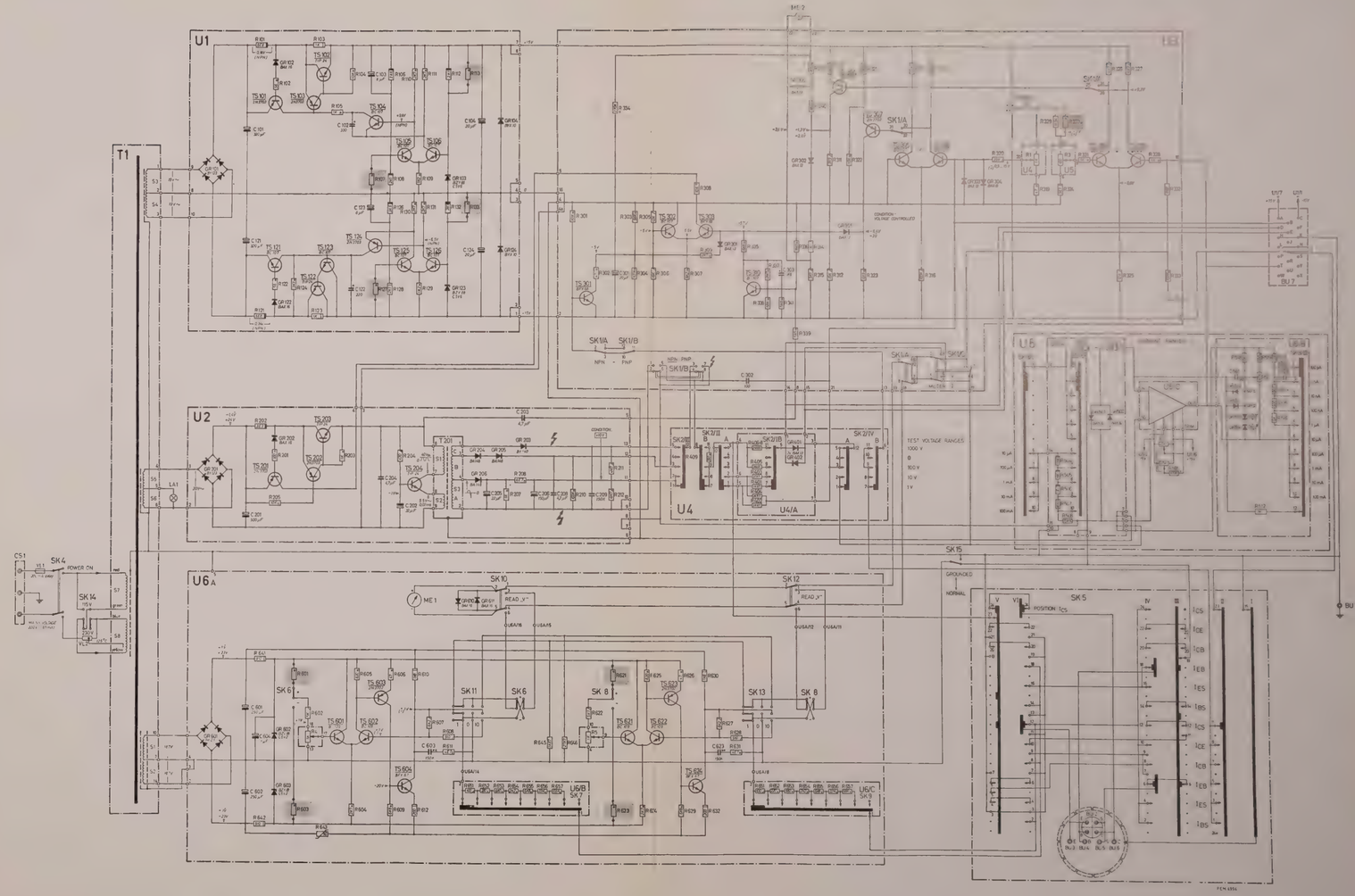


Fig. 47. Circuit diagram

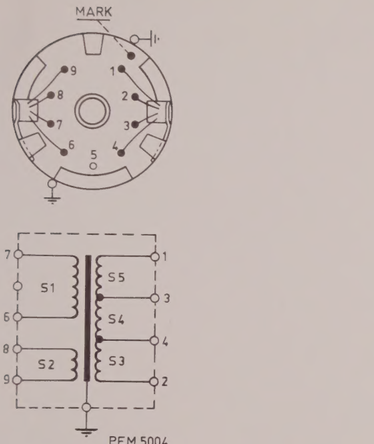
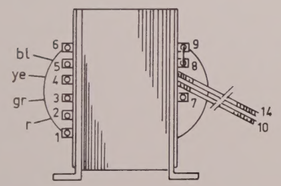
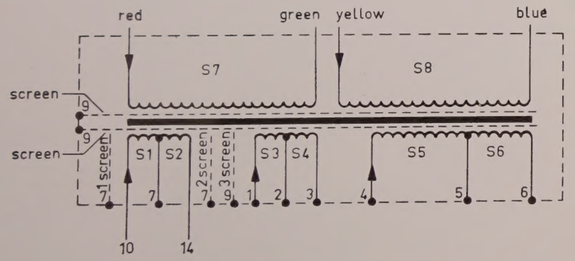


Fig. 44. H. T. Transformer T201





UNLOADED TRANSFORMER VOLTAGES							
S1	S2	S3	S4	S5	S6	S7+S8 in series	WINDING
19.6	19.6	19.6	19.6	15.5	5.5	220	VOLTS
122	122	122	122	97	33	675 EACH	TURNS

PEM 5003

Fig. 45. Mains transformer

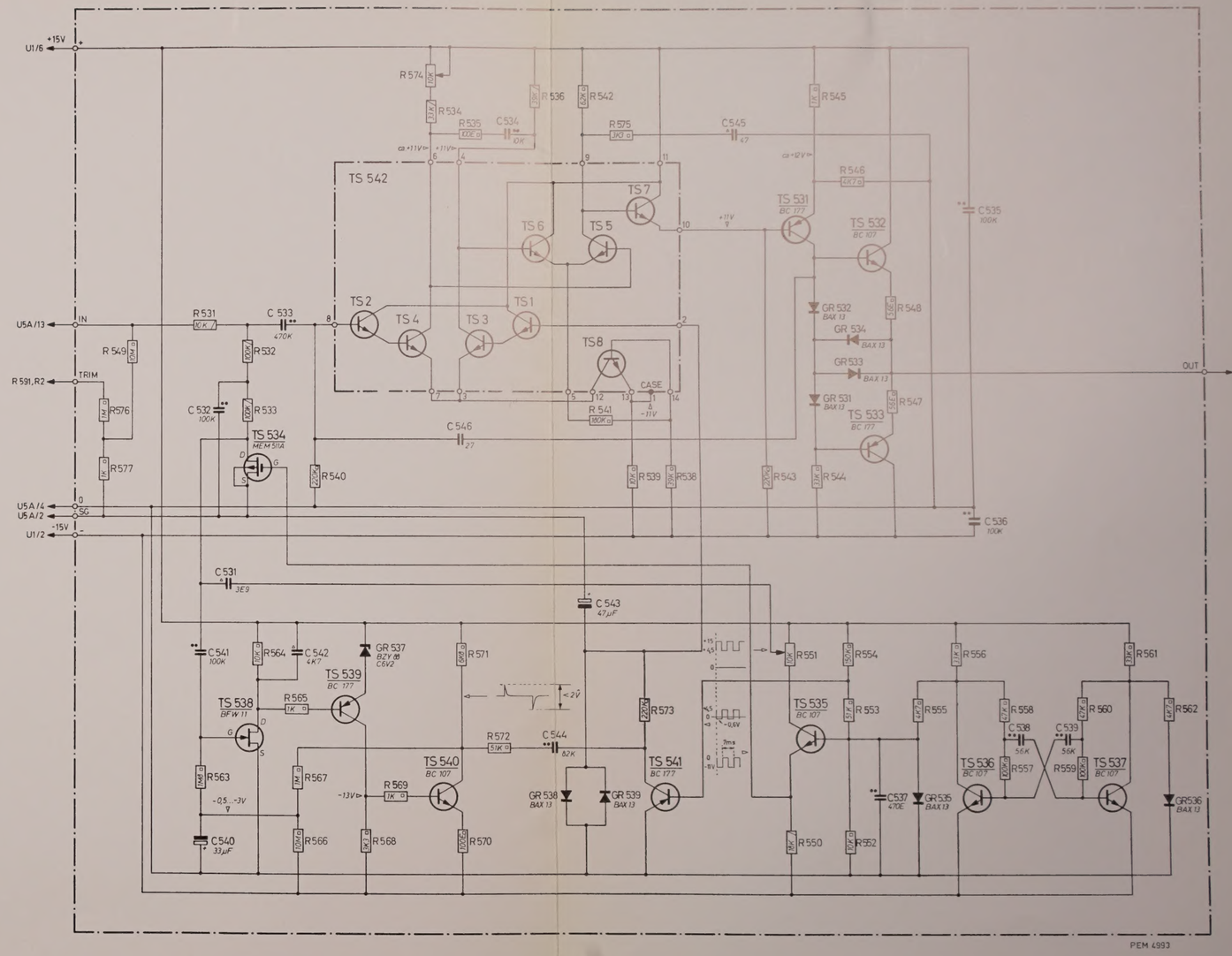


Fig. 46. Principle diagram of operational amplifier U5C

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